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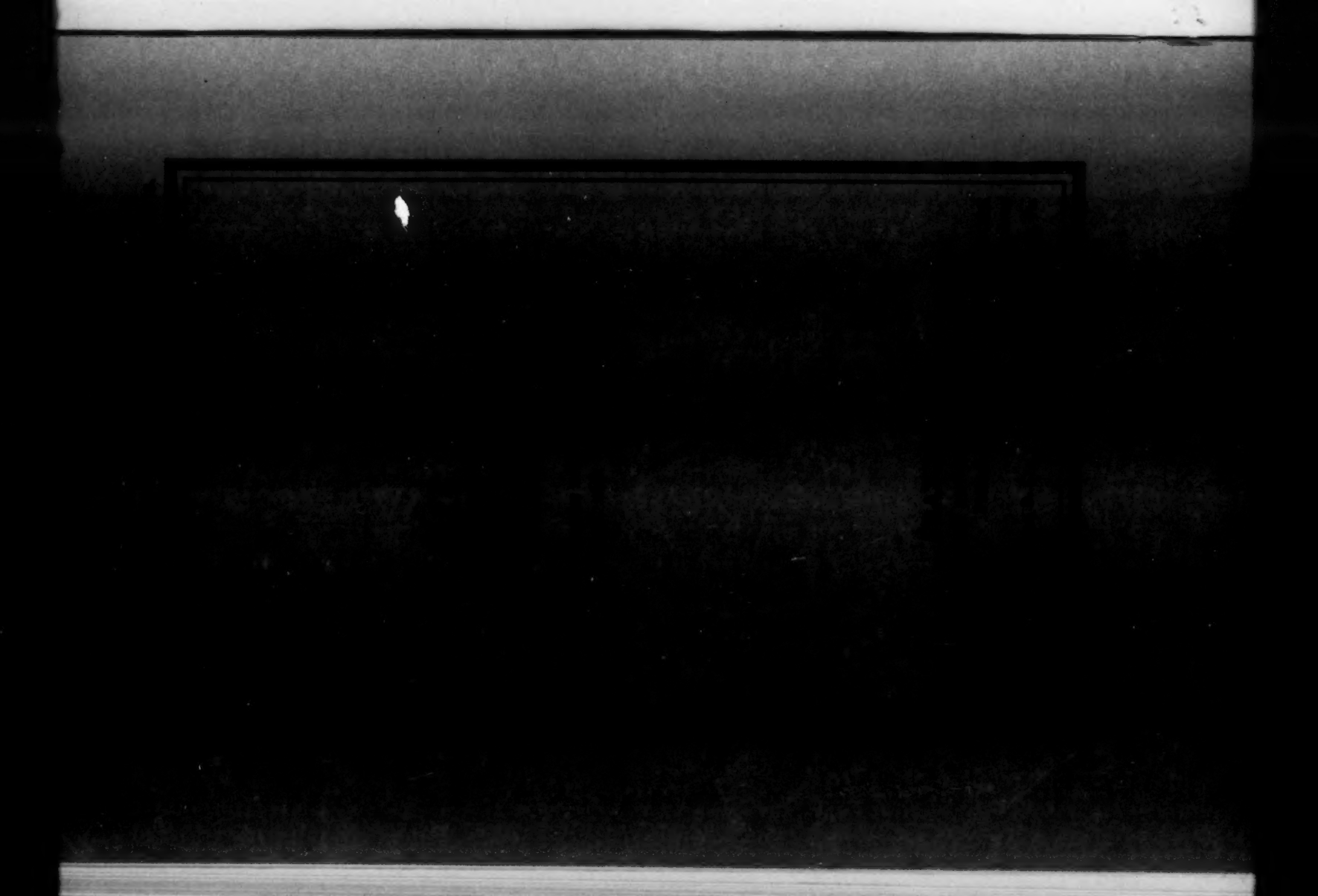

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THE DESIGN OF WAR VESSELS AS AFFECTED BY THE WORLD WAR.*

BY

REAR ADMIRAL DAVID WATSON TAYLOR.

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THE Battle of Trafalgar was fought October 21, 1805, or early in the nineteenth century. In the early part of the present century the tactics employed in that battle were still being discussed, but although Nelson's Flagship, the *Victory*, is preserved by England at Portsmouth, it is of no interest from a material point of view to designers of war vessels of the present day. Similarly, with the rapid engineering development of naval material which has been going on for more than fifty years and bids fair to continue, the material lessons from the World War must be gathered within a comparatively short time. Even so, to answer fully the question, "What has been the effect of the World War on warship design?" is not as yet possible. For years it will be necessary to collate and study an enormous mass of experience, some written, some oral, some originating from the responsible controlling bodies of the great navies, and much from individuals, including not only those of great eminence, but many whose names will never emerge from comparative obscurity,

* Presented at the Stated Meeting of the Institute held Wednesday, April 21, 1920.

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though their experience in the aggregate may in the long run exercise a dominating influence.

As a practical proposition the full effect of war experience will be demonstrated in concrete form only after service opinion has been crystallized and become definite in direction as a result of study and discussion by a large number of officers. Certainly that will be the case in the American Navy where the organization is such that service opinion necessarily controls policy in the development of naval types. The service is a customer of the naval designer, and although the latter may influence and at times interpret and lead service opinion, the customer will have what he demands. What I say to-day must therefore be taken more in the light of a discussion of this intensely interesting subject, than as a hard-and-fast laying down of principles or expressions of final opinion.

Let me call attention at once to the fact that, after all, there has been nothing startling or revolutionary brought about by the experience of fifty-one months of war. There has mainly resulted an intensive development of each of the accepted types which existed at the outbreak of the war and which were the results of many years of study, experiment, and practice in all of the great navies of the world. It is true that some new types have appeared, but with one exception, namely, aircraft carriers, they have been of minor importance when measured by the cost and time required for production.

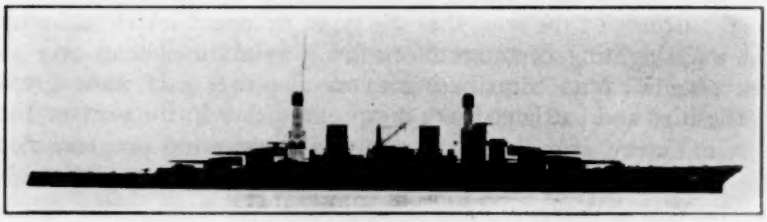
When we consider types and not details, we must not look only to the few naval battles of the World War which can justly be classed as major actions for the influences affecting our naval construction of the future. It is necessary to consider the particular trend of naval events, the accumulated experience, and the principal phases of naval activity during the more than four years of hostilities.

The first of these must naturally be the causes which gave not only the initial but the continuing command of the sea to the Allies. We know that at the outbreak of the war all German mercantile vessels quickly disappeared from the high seas, being either held in their own ports or promptly interned in neutral ports. On the other hand, Allied commerce proceeded on its way. It was not the great British Battle Fleet which the German merchantmen feared, for they knew that this Fleet would be con-

centrated at one point within easy striking distance of the German coasts and therefore it could be easily avoided. What they feared were the Allied Cruisers, Auxiliaries, Destroyers and light vessels of every class. Just as the few German Cruisers which were at large were captured or sunk within a few months, so could this cloud of Allied light craft have been swept from the seas had the German heavy fighting forces been able to operate without first giving battle to the superior British Battle Fleet. They were unable to do this at any time during the war. As a result every military effort of the Central Powers afloat and ashore was made more difficult because of the slow but sure throttling of their economic and industrial life. Without the British Battle Fleet the blockade of Germany would have been ineffective. This factor had such a determining influence, both on the duration and final outcome of the war, that the types of vessel which make up the main fighting fleets are more firmly established than ever as the essential ones contributing to naval power. If these great battleships and battle cruisers disappear, either in the near or the distant future, it will be as a result of engineering progress and the invention and perfection of new weapons and not as a result of the World War.

Battleships and battle cruisers were in actual conflict with vessels of the same type and power on only two occasions: at the Dogger Bank on January 24, 1915, and at Jutland on May 31, 1916. These actions, however, do not by any means represent the sum total of their activity. When the location and activity of the German Cruiser Squadron in the Pacific was disclosed by the tragedy off Coronel, two battle cruisers at once sailed to search out and destroy this troublesome squadron. Perhaps they were lucky in coming into contact with the enemy immediately, but the celerity and success with which they accomplished their mission at the Falkland Islands gave a great impetus to the favor in which this type was held by naval men. The immediate effect of this sentiment was seen in the British battle cruisers *Repulse* and *Renown*, which represent the extreme of the type; that is, armor and gunpower were sacrificed to speed to an even greater extent than in the original battle cruiser. These were quickly followed by an even greater extreme, the *Courageous*, *Furious* and *Glorious*, which can be denominated either small light battle cruisers or enormously large light cruisers, as they

have the largest guns characteristic of the former and the total absence of armor protection characteristic of the latter, while possessing the high speed common to both. The battle off Dogger Bank served only to confirm the conclusions on which these two classes of ships had been laid down. In this engagement, the rival battle cruisers met for the first time, with the result that those on both sides demonstrated their ability to stand heavy punishment without succumbing to fatal damage. Even the older German cruiser *Blucher*, which was inferior in gunpower, protection and speed to all of the others, succumbed only after surviving for a considerable period of extremely heavy punishment. If there had been no further war experience with the battle cruiser type it is likely that the idea that protection is not im-



U. S. BATTLE CRUISERS NOS. 1-6.

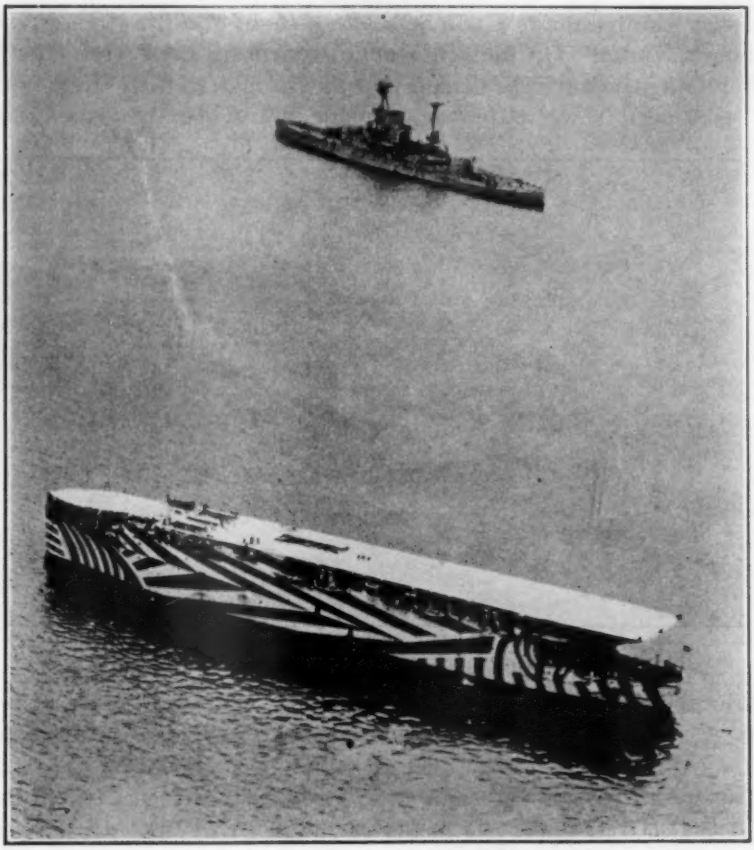
Principal characteristics:

Displacement	43500 tons	Speed	33.25 knots
Length	850 feet	Battery	8-16" and 16-6" guns
Horsepower	180000	Torpedo tubes	4-21" submerged and 4-21" above water

portant for them would have prevailed, and the combination of extreme speed, guns of the largest size, and the minimum of protection might have been in favor for some years. But the Battle of Jutland gave a rude shock to opinions based on earlier actions.

The Battle of Jutland is easily the foremost single event of modern naval history. The controversial phases of the tactics employed in this battle are only of interest to the naval designer in so far as the material in the two fleets influenced the judgment and decisions of the high command on each side, and to the extent that new instruments of naval warfare, not then available but developed since, would have exercised a determining influence in the tactics employed; in the latter class comes the use of aircraft, and I will have occasion later in this paper to refer to the

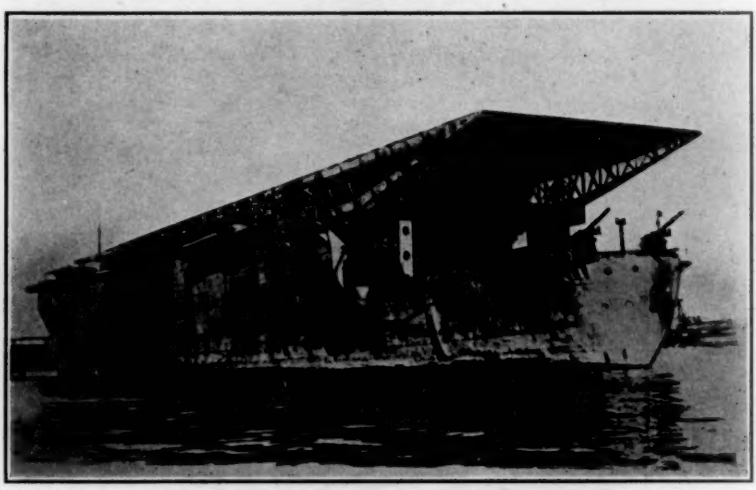
use and influence of aircraft in naval operations from the designer's point of view. By far the most important aspect of this engagement to the designer is the manner in which the various types of vessels engaged fulfilled the functions for which they were originally designed. In regard to type, the first outstanding



BRITISH AIRPLANE CARRIER *ARGUS*.

fact is that battle cruisers must inevitably play an important rôle in major fleet actions. Each side in turn, first the Germans and then the British, used their battle cruisers to lead the whole or a portion of the enemy's fleet to contact with the main body of their own fleet. In fact, with the sing'e exception of the *Warspite*,

it was the battle cruisers on both sides that stood the brunt of the action and received the lion's share of punishment from the enemy. If the battle had been fought to a finish between the battleships, there might have been a different story to tell. The losses and heavy damages sustained by the vessels of battle cruiser type bear out to some extent the pre-war contentions of those who maintained that it was not fit to take its place in the line of battle. On the other hand, excepting their greater vulnerability, it cannot be denied that they acquitted themselves with credit even when pitted against the more heavily armed and



BRITISH AIRPLANE CARRIER *ARGUS*.

armored battleship. Furthermore, not only was the value of their great speed demonstrated, but also the value of one side holding the speed gauge over the other was shown, for, it was due to the possession of higher speed by the British that the German Fleet, at the end of the second phase of the battle, found itself in a position which was so bad tactically that the German Chief-of-Staff is quoted as saying that if any Admiral had involved himself in such a position in peace time manœuvres he would never again have obtained a command afloat. Another result from this action of general influence on type is found in connection with the use of older battleships, generally referred to as of the " Pre-dreadnaught " era. The German Fleet included

one squadron of vessels of this type, and this squadron not only failed to be of any essential assistance to them but proved actually to be a handicap on their freedom of manœuvre. The force of this lesson was shown by the fact that subsequent to the battle most of the German battleships of this type were retired from active commission. The material weakness of this type of older ships, when opposed to the most modern weapons, was shown in the case of the *Pommern*, which blew up and sunk immediately as a result of a single torpedo. The ineffectiveness of these older ships, as shown by many incidents of war, will be referred to later.

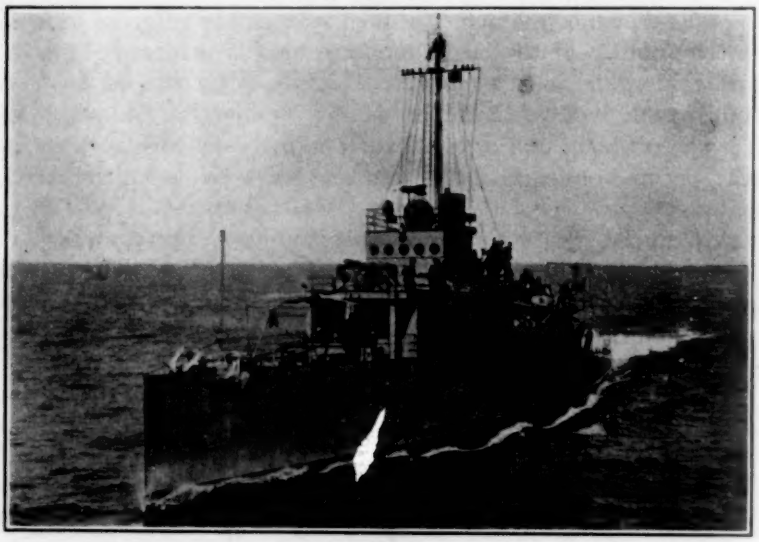
The ability of the large, modern, heavily-armored ships not only to survive, but to continue in action after the most severe punishment, was perhaps best shown by the British battleship *Warspite*, which, due to an unfortunate accident to the steering gear, sheered out of the battle line and made two complete circles within short range of the German Fleet. This vessel was hit by major calibre shell between 20 and 25 times. The net result of this tremendous hammering was that one out of eight 15-inch guns was put out of action; there was no damage of any kind to her main machinery plant; the upper works and unprotected portions of the ship were riddled; communications were interrupted to a considerable extent; and some compartments at and below the waterline were flooded by water which came in from above, but none of the main compartments were affected to such an extent that the entering water could not be handled by the pumping arrangements provided. In short, although the ship had lost a certain amount of her margin of safety, due to decreased buoyancy and stability, and her speed had suffered on account of increased resistance due to her greater draft, she was entirely capable of resuming action after adjustments to her steering gear.

The *Marlborough* was another example of a battleship continuing in action after receiving what we were inclined formerly to consider would be a disabling attack. This vessel, although of the "Dreadnaught" era, has not what is now considered a highly efficient form of protection against torpedo attack, yet, after being struck by a torpedo, resulting in the flooding of a number of compartments, which produced a list of about 7 degrees, the vessel continued in action at a speed of 17 knots.

Similarly, the German battleship *Ostfriesland* (of the "Dread-

naught" era) was struck by a torpedo which produced some flooding, but the vessel was otherwise unaffected and continued on with the German Fleet.

No other British battleships received any considerable amount of punishment, but three of the modern German ships of this class received, respectively, 7, 7 and 13 hits from major calibre guns, but none of them were disabled or even damaged to an extent sufficient to prevent them continuing in action. The *Markgraf*,



EAGLE CLASS.

Principal characteristics:

Displacement	500 tons	Speed	18 knots
Length	200 feet	Battery	2-4" guns
Horsepower	2500	Depth bomb projector	1 Y-type

which was struck 13 times, is a particularly illuminating example of the amount of punishment which a modern heavily armored ship can stand. The only damage affecting the efficiency of the ship was the cutting of the communications from the masthead fire control positions, and this only resulted in shifting the control to the lower armored station provided for this purpose. The casualties on this ship were likewise remarkably low, as there were only 8 dead and 9 wounded, or only a little more than one casualty for each major calibre hit.

One particular class of hit of special interest to American designers is that in which turrets or their barbettes have been hit. Taking the case of 4 British and 4 German vessels which suffered heavy damage, it is found that out of a total of about 116 hits, 19, or 16.5 per cent., were on turrets or barbettes, of which 16 were struck. Of this number, 4 were completely put out of action and one gun in each of four others was disabled, while the remaining 8 escaped without serious damage. In other words, out of 66 big guns carried by these ships, the emplacements of

BRITISH BATTLE-CRUISER *HOOD*.

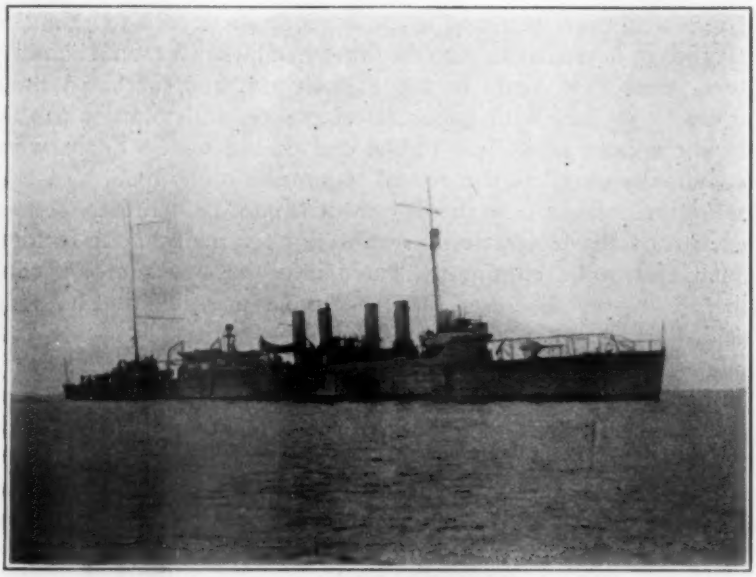
Displacement	41500 tons	Speed	31.25 knots
Length	860 feet	Battery	8-15" guns
Horsepower	144000		

32 were struck, but only 12 were sufficiently damaged to prevent their further use. This comparatively low proportion of casualty in the major offensive armament, together with the demonstration of the ability of the mechanism of a turret to continue to function even after the turret has had a direct hit, appears to dispose of the argument of "too many eggs in one basket" so frequently advanced against the American three-gun turret.

Turning to the damage sustained by the battle cruisers, one's attention is naturally taken first by the tragic loss of the three great British vessels of this type. Although in one case the

Germans claimed a torpedo hit on one of them, it is generally accepted that the loss of all three was directly attributable to gunfire, but the immediate cause of the loss in each case is still, and always will be, shrouded in mystery. It is, of course, known that each one sank in an appallingly short interval of time and that in each case at least a portion of the magazines blew up. The mystery lies in the immediate cause of the magazine explosion. Many different explanations have been advanced, but all of these affect details of design rather than the general characteristics of type. There seems little doubt that one of two things happened: German shell either entered the magazine through penetration of the protective deck, or, having pierced turret or barbette and exploded, flame was communicated to the magazine along the path followed by the ammunition from magazine to gun. From the fact that in the case of the British ships that survived, there was only one case of penetration below the protective deck at any part (no harm resulted from this), it would seem to be highly improbable that the three battle cruisers were all sunk by protective deck penetrations directly over the magazines, and not very probable that any one of them was so sunk. We must not permit our judgment to be swayed too largely by this particularly spectacular phase of the battle. Just as in the case of the battleships previously referred to, the remaining battle cruisers on both sides demonstrated ability of modern ships of large size to withstand heavy punishment without losing their fighting efficiency. The battle cruiser type is essentially and unavoidably less thoroughly protected than the battleship type. This greater vulnerability must result in greater loss of the battle cruiser type, other things being equal; but in the Jutland fight the battle cruisers were engaged much longer and much more severely than the battleships, so that a greater percentage of loss of this type should have resulted even had their protection been equal to that of the battleships. A notable fact in regard to the modern ships, both battleships and battle cruisers, on both sides, is that not a single one experienced a disabling casualty to its machinery, either as a result of damage from enemy fire or as a result of engineering breakdown. In the case of one British ship and one German ship, fires were drawn from under the boilers in one fireroom, due in each case to leakage from adjacent compartments, but in each case this leakage was controlled by the pumping plant

provided for the purpose. Leaving out the three lost battle cruisers, for which no data is available, the dozen large ships in the two fleets which bore the brunt of the punishment were hit a total of about 150 times by large calibre shell, or an average of more than 12 times each. Only one of these dozen ships, namely, the German battle cruiser *Luetzow*, sunk as the result of the damage received. Even this vessel sank only after 6 hours.



DESTROYERS. 186 CLASS.

Principal characteristics:

Displacement	1215 tons	Speed	35 knots
Length	310 feet	Battery	4-4" guns
Horsepower	27000	Torpedo tubes	4-21" triple

She had received 17 large calibre hits and one torpedo. She continued to try to make the best of her way to port, but the struggle was given up about one o'clock in the morning; her crew was taken off by destroyers and she was finally sunk by a friendly torpedo.

The results of the battle, as a test of the defensive qualities of capital ships, show that in the entire action only 4 modern armored ships, all of them of the battle cruiser type, were lost as a result of the action. This was out of a total of 14 engaged and at least 7 out of the remaining 10 survived heavier punishment

than most designers in pre-war days would have considered possible.

Before the war there were two distinct schools of Naval thought in regard to the main armament for the largest fighting ships. This difference of opinion existed internally in probably every navy, but internationally the American and British Navies represented the "Big Gun" advocates, as is shown by the fact that in the former we find successive increases from 12 inch to 14 inch to sixteen inch, and in the latter from 12 inch to 13 and a half inch to fifteen inch. On the other hand, the Germans adhered for a number of years to the 11-inch gun and increased their calibre to 12 inch with apparent reluctance, and a larger calibre did not appear until close to the end of the war. There were undoubtedly excellent theoretical arguments on both sides of this contention. Even now the argument cannot be definitely settled in terms of absolute material results, for too many other factors, which cannot be eliminated, enter into the problem. A convincing answer, however, appears to be provided in the very decided trend of German Naval opinion since the Battle of Jutland. Practically every report from German sources and every German publication bearing on the Battle of Jutland lays stress on the superiority in range and accuracy of the British 15-inch guns. Even if no definite material advantage for the larger calibre gun could be established, here appears to remain a marked moral superiority on the side possessing the biggest guns. This, of course, only confirms the previous views and policies followed in our service.

Summing up, therefore, we find that four outstanding facts of interest to the designer appear to emerge from the smoke and flames of the battle:

First. The value of armor protection.

Second. As a corollary to this, the necessity for the maximum number of major calibre guns; for, if the modern ship can withstand great punishment, we must, for purposes of offence, provide a sufficient number of guns to inflict a degree of punishment which will be fatal.

Third. The tactical value of speed.

Fourth. The futility of subjecting older ships to the attack of modern weapons.

In other words, the value of each one of the three major

elements entering into capital ship design was demonstrated and it cannot be said that any single one has emerged with an importance transcending that of the others. If, however, one must choose among them, the consensus of opinion will probably attach more importance to protection than before the battle. This arises largely from two causes:

1st. The deep impression on the human mind by such an out-

SUBMARINE CHASERS.

Principal characteristics:

Displacement	77 tons	Speed	18 knots
Length	110 feet	Battery	1-3" gun
Horsepower	660	Depth bomb projector	1 Y-type

standing tragedy as the almost instantaneous loss of the three great British battle cruisers.

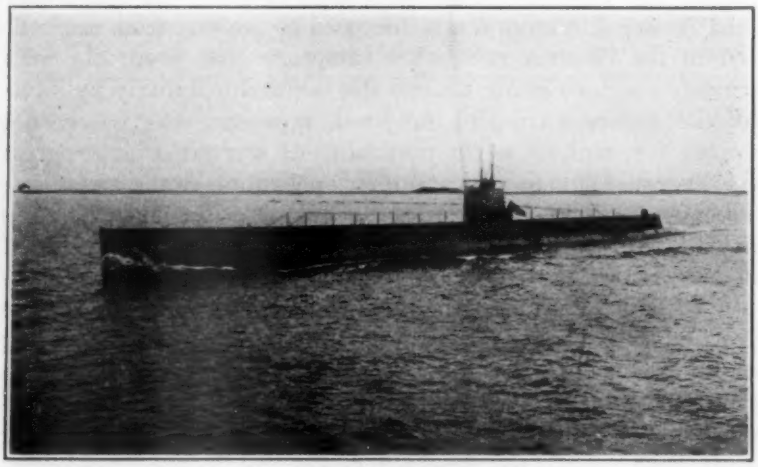
2nd. The impression that German ships, generally speaking, stood punishment better than the English. Admiral Von Tirpitz has been reported to have laid down as the fundamental principle of German design: That vessels before everything else must float; that they must not sink, and if possible, not even list, and that all else is of secondary importance.

This emphasis on the feature of protection is shown already by the intensified and successful efforts of both the British and the American Navies to perfect an efficient form of torpedo protection. In this connection, I think I can safely say that both services have solved this problem so far as the torpedo has been developed to date. It is also interesting to know that during the war the two services frankly and fully compared their solutions of this problem, and that although the solutions differ radically in details, they do not differ much in underlying ideas and both are believed to be successful in result. This emphasis of the protective feature is further shown by the fact that our battle cruisers, whose construction was delayed, due to the necessity for our concentrating on the construction of torpedo craft and merchant vessels during the war, have been re-designed and given much heavier and more complete protection than was originally contemplated, accepting at the same time the slight decrease in speed necessitated thereby. We find precisely the same influence in the case of the latest British battle cruiser, the *Hood,* which was laid down shortly after the battle of Jutland and in which we find more than a 50 per cent. increase in size as compared to their *Renown,* which I have previously referred to, an increase of protection almost to a battleship standard and a decrease in speed.

Turning to the lighter craft used in the Battle of Jutland, it will be found that at several critical times during the engagement both sides used their light cruisers and destroyers to obtain a tactical advantage. Each side likewise used craft of this character to repel the attacks of similar vessels of the enemy. Although the material effect was small, there being probably not more than six torpedo hits on the large vessels of both sides, the necessity for their use is clearly demonstrated not only by their success in obtaining certain tactical advantages, for which they were used, but also in the demonstration that if either Fleet had been without these light craft, the torpedo casualties inflicted on the big ships by the light craft of the side possessing them would have been enormously greater. The losses of light cruisers and destroyers on both sides were heavy in actual number, but not in proportion to the total number engaged, as will be seen from the following table:

	Light Cruisers		Destroyers	
	No. Lost	No. Engaged	No. Lost	No. Engaged
British	0	26	8	78
German	4	11	5	77
Total	4	37	13	155

Submarines played no direct part in this battle, and it is reliably established that neither Fleet was accompanied by submarines, nor were there any submarines even within striking distance of the scene of action.



U. S. SUBMARINE A A 1.

Principal characteristics:

Displacement (surface)	1106 tons
Length	269 feet 9 inches
Horsepower (surface)	4400
Speed (surface)	20 knots
Battery	1-4" gun
	2 Deck torpedo tubes aft.
	4 Bow torpedo tubes forward

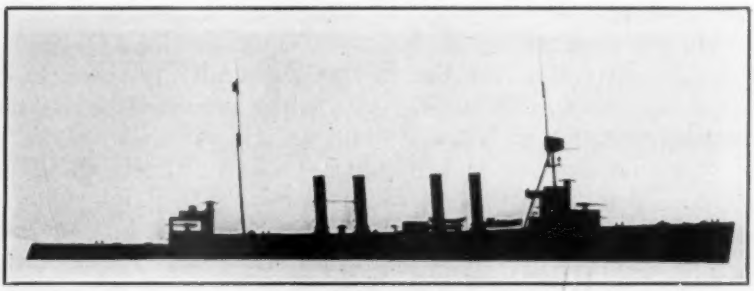
Similarly, aircraft played no part in the action, although it is understood that it was part of the German plan to utilize Zeppelins for scouting purposes in connection with the sortie of the Fleet and that this was only prevented by unfavorable meteorological conditions on the 31st of May. On the following morning, however, German aircraft were out over the North Sea and were undoubtedly of some small assistance to the German Fleet in insuring their safe withdrawal to their harbors.

Passing once more to the general phases of the war, we come

at once to the outstanding feature of the war at sea, the submarine campaign and the methods adopted to combat it. Now that the veil of secrecy has been lifted, we all know how close the German submarine campaign came to being an outstanding factor in the final result. Without entering into the legality and ethics of the German use of the submarine against merchant shipping, which all thoughtful and enlightened men join in condemning, we cannot escape the fact that we must in the future be prepared to find the submarine playing an important part in attacking and throttling enemy commerce, even on their own coasts. This is indicated by the result of the discussion at the Peace Conference when the world at large was so incensed by the barbarous methods used in the German submarine campaign that proposals were seriously put forward to abolish the submarine entirely by international agreement. This proposal, however, was wisely not adopted for, so long as the possibility of war remains, progress of science and engineering and their application to the art of war cannot successfully be throttled unless there is complete unanimity of sentiment throughout the civilized world. The use of submarines during the war has led to placing very great emphasis on the value of radius of action of these vessels, and with radius of action there must go hand in hand improvements in the living conditions on board, so that the physical endurance of the personnel may be sufficiently conserved to permit it to make full use of the material capabilities of the vessel. Both of these elements, even without the usual and concurrent demands for higher speed and greater offensive power, inevitably lead to increased size, except for a limited class of small boats, which, due to a particular strategic situation, such as that occupied by the Germans on the Belgian Coast, makes it possible to use with good results a large number of submarines of small size and limited speed and cruising radius. The technic of mine-laying has, during the war, so kept pace with the strategical and tactical demands for the use of this weapon, that the demonstrated practicability of laying them on the enemy's coast by means of submarines must in the future be taken into account, but this does not affect the general characteristics of the type, as the mine-laying feature can easily be substituted in whole or in part for the torpedo armament. Although the submarine was throughout the war something of a disappointment in the actual results which it obtained

in inflicting loss or damage on the fighting ships of the enemy, its indirect effect on the freedom of action of the main fighting fleets was so considerable that the problem of the development of the so-called fleet submarine is still with us and must be solved largely from theoretical and engineering considerations, rather than from direct experience in action. Another use of the submarine, not largely foreseen, which developed considerable importance during the war, is that of scouting. It has been conclusively demonstrated that these underwater craft form one of the most valuable assets to a navy in obtaining and transmitting information in regard to the movements of the enemy's forces.

War experience developed and emphasized certain facts



U. S. SCOUT CRUISERS NOS. 4-13.

Principal characteristics:

Displacement	7100 tons	Speed	35 knots
Length	550 feet	Battery	8-6″ guns
Horsepower	90000	Torpedo tubes	2-21″ submerged

regarding submarines as a type which are very important from the point of view of a designer, and even more important from the point of view of those who have to determine the constitution of a navy. The submarine is essentially an instrument of stealth. Once detected, it must take refuge in the depths where, for any design yet known, its offensive powers become nil, and to the depth charge or explosive bomb developed during the war it is exceedingly vulnerable. In other words, once detected and accurately located, a submarine is at the mercy of a surface vessel. While detection devices, in spite of the enormous effort expended upon them during the war, did not reach perfection, they made much progress and will undoubtedly be steadily improved as time goes on. If we had to-day an accurate device

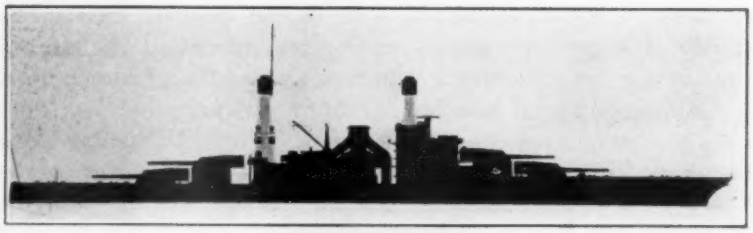
which would locate a submerged submarine with reasonable approximation several miles off, and with accuracy when one or two hundred feet directly under the surface vessel, the submarine would be already obsolete as a weapon of war. While we may never reach this ideal, and while the submarine may be given offensive features to enable it to deal in some fashion with the surface vessel from beneath the surface, the submarine is essentially a vulnerable, and, if I may so express it, a precarious type; is necessary to-day and probably will be for many years to come, but could not be relied upon as the main feature of a navy. We read at times of proposed submersible battleships and other such imaginations, but the experience of the war does not seem to indicate this as a probable future development even if mechanically possible.

On this same subject Sir Eustace d'Eyncourt, the Director of Naval Construction for the British Admiralty, very recently stated his views in the course of a paper presented before the British Institution of Naval Architects. He said:

"A good deal has been written and talked of lately about the surface Capital Ship being dead and the necessity for submersibles. But with our present knowledge it would be quite impossible to design a submersible ship which on the same displacement and cost had anything like the fighting qualities on the surface, which are possessed by the *Hood* (the latest British Battle Cruiser). Every ship is a compromise, and if in addition to the ordinary qualities of a battleship, she is required to submerge, or even partially submerge, a very considerable percentage of weight has to be added to give her this additional capability of submergence. She becomes still more of a compromise, and the added weight must detract from the fighting qualities of the ship when on the surface, so that whatever is done, other things being equal, the submersible ship must be inferior to a surface ship in an ordinary action. There are many difficulties of details in the design of a submersible battleship which would take too long to go into fully now, and although there is no doubt that submarines are capable of great development, a little thought will make it clear to anybody that if naval warfare is to continue, the surface ship of the line must still hold the field as the principal fighting unit of any great navy."

Considering types of war vessels existing at the commence-

ment of the war, the position of the Destroyer has been enhanced perhaps more than that of any other, and this has been brought about by our experience in its use against the submarine. As mentioned above, in discussing the results of the Battle of Jutland, the Destroyer has established its indispensability for use with the Fleet, both to attack the enemy and to protect its own capital ships. This use, however, was foreseen and provided for to at least a limited extent in all of the principal navies of the world before the war. It was not, however, foreseen that this type of vessel would be required in undreamed-of numbers to protect the sea lines of communication from the lurking underwater enemy. During the first three years of the war, it had already been found that the destroyer was the most efficient type of vessel



U. S. BATTLE SHIPS NOS. 49-54.

Principal characteristics:

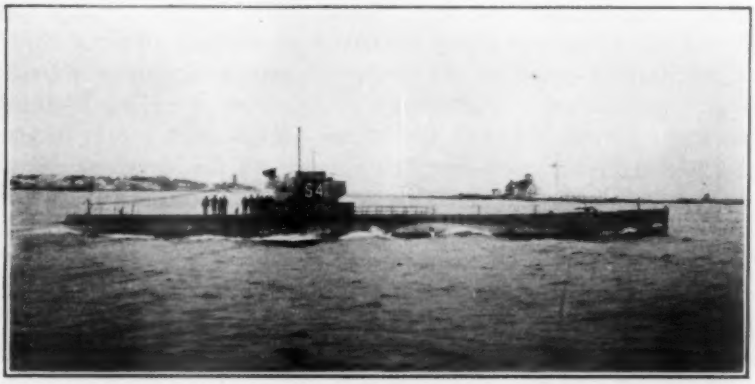
Displacement	43200 tons	Speed	23 knots
Length	660 feet	Battery	12-16" and 16-6" guns
Horsepower	60000	Torpedo tubes	2-21" submerged

for hunting down and destroying submarines, and for convoying or protecting a particularly valuable transport or cargo ship. In the spring of 1917, however, the losses of merchant vessels had reached such an alarming rate that the responsible authorities recognized that a new and radical method of protection must be adopted. It was then that the convoy system was put into effect, and soon proved its efficiency to a degree which could hardly have been foretold. It became then imperative that convoy should be provided as nearly as possible for every ship approaching England and France. The only available type of vessel which could perform this very arduous service, requiring many days continuously at sea in all kinds of weather, frequently at very high speed in order to accompany high speed transports, was the destroyer. This demand placed a tremendous strain on the resources of the

Allies in this type of vessel, and it is now a historic fact that the United States Fleet was stripped of its destroyers which were sent to the war zone to perform this service, and that British destroyers were detached from the combined British and American Battle Fleets, upon which we depended to maintain our command of the seas, until that Fleet was actually seriously inferior to the German Fleet in destroyer strength. From our entrance into the war the United States Navy concentrated upon destroyer building, its destroyer construction undertaken during the war being on a scale never before considered possible. It is a matter of congratulation that this has resulted in our now possessing a fleet, built or to be completed this year, of more than 300 modern destroyers of the most efficient type. In regard to the effect of the war on the characteristics of destroyers, the principal demand has been in the same direction as in the case of submarines, namely, for greater cruising radius and increased shelter and comfort for the personnel. Whereas, during the greater portion of the time of actual hostilities, convoy was provided for transports and cargo vessels only in the so-called Submarine Zone, extending 300 to 400 miles off the European Coast, it had become evident before the Armistice that as soon as we had sufficient destroyers for the purpose, escort would have to be provided, at least for the most important groups of vessels, entirely across the Atlantic. This was brought about by the ever-increasing tendency of the German submarines to operate farther afield and by the approach to completion of a very large type of cruiser submarine, which it had been known for some time was under construction in Germany in considerable numbers. The later United States destroyers would have been prepared to cope with such submarines, as the size of their guns had been increased from 4 inches to 5 inches. To obtain these increased qualities without considerably increasing the size of the boats, which was of course undesirable under the emergency demand for quantity production, meant the acceptance of a small decrease in speed. This we could accept with equanimity as our destroyers were already somewhat superior in speed to the latest types of corresponding size abroad.

The necessities of the anti-submarine campaign brought about new uses for several existing types of vessels, and the development of several new types. It had always been contemplated that fish-

ing trawlers, drifters and other small vessels of similar type could be used in time of war as mine sweepers and tenders. With the development of the depth charge, a bomb containing about 300 pounds of high explosive with a detonating mechanism, which functioned only when it had sunk to a certain predetermined depth below the surface of the water, it became evident that any small type of vessel possessing the necessary seagoing qualities could be usefully employed against the submarine. As a consequence, this became the principal use to which these small fishing boats were put during the last year and a half of the war. They could not, of course, perform the high seas functions of the



U. S. SUBMARINE S 4.

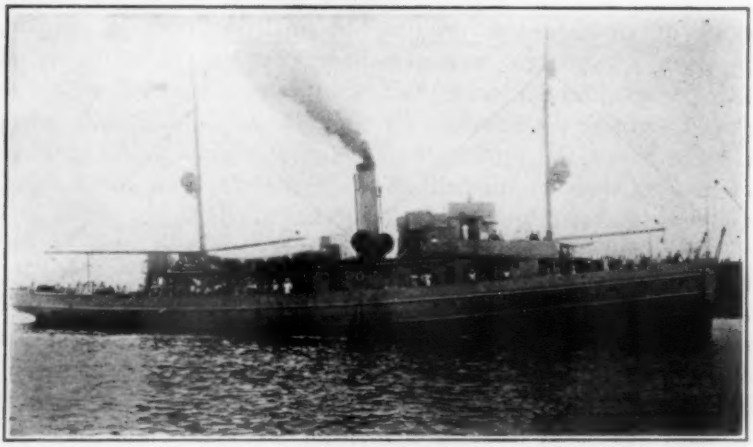
Principal characteristics:

Displacement (surface)	876 tons	Speed (surface)	15 knots
Length	231 feet	Battery	1-4" gun
Horsepower (surface)	1400	4 Bow torpedo tubes	

destroyer, but they proved most efficient for hunting operations and for coastal convoy purposes. The esteem in which they were held is shown by the fact that in the summer of 1917 the British Navy put in hand a construction program of more than 500 of these little craft. The limitations on the use of the fishing boats and the limitations on the production of the destroyer, due to its large size and cost, resulted in the development of intermediate types which would give good seagoing qualities combined with a speed comparable to the surface speed of the submarines themselves, and at the same time sufficiently small and simple in construction to permit of their production in large numbers.

The British patrol boats and the United States Eagle boats are the principal examples of this type. The latter is really a small destroyer of 200 feet in length and 600 tons' displacement, having a good cruising radius and a speed of 18 knots and carrying an armament of two 4-inch guns with unusually good command and a large number of depth charges, together with the various devices for dropping or throwing these bombs. The British also developed and turned out a considerable number of a somewhat larger type, which were known as " Sloops," which were given a slower speed but a larger cruising radius, together with a more robust type of construction and special features to insure their buoyancy in case of damage by torpedo. All during the war, as previously referred to, the best scientific talent, both in this country and abroad, was making every endeavor to perfect devices which would permit a vessel on the surface to hear a submarine moving below the surface. Various types of these so-called listening gears were developed and some attained a sufficient degree of success to exercise a considerable influence on the development of types of vessels from which they could be used with the maximum of efficiency. It was in fact the development of these devices in America which led to the laying down of our Eagle boats, and the machinery of these boats was designed with especial view to quick starting and stopping, so that internal noises should not in any way effect the use of the listening devices. Even before our actual entry into the war, it had become evident that it would be necessary for us to produce, in the minimum of time, the maximum number of vessels of every type which could be utilized against the submarine. This led to the planning of our program of sub-chasers. Earlier in the war, the British had purchased in this country over 500 gasoline-driven wooden hull boats of 85 feet in length for general coastal use. Their experience indicated that there was a distinct field of utility for vessels of this class, but that they should be of a somewhat larger size with better sea-keeping qualities. In order, therefore, to profit by their experience and at the same time to utilize the considerable resources in this country for the construction of small wooden hull vessels, resources which were not required in the accomplishment of any of the various other war programs, we undertook the construction, immediately upon entering the war, of 350 of these sub-chasers, each 110 feet in length, about 75 tons displacement, and having

three 200-horsepower gasoline engines, giving a top speed of about 16 knots. They were fitted with special facilities for the use of various types of listening gear. They carried one small gun and a number of depth charges. In their seagoing qualities, these boats more than met the anticipations of their designers. About 200 of them crossed the Atlantic under their own power and performed most useful service in the Mediterranean Sea and on the French and English Coasts. However, these boats must be regarded as stopgaps rather than a type to be found in large numbers in a permanent navy.



MINE SWEEPERS.

Principal characteristics:

Displacement	950 tons	Speed	14 knots
Length	180 feet	Battery	2-3" A A guns
Horsepower	1400		

Another class of operations which resulted in the development of a new type, or rather the resurrection with new features of an old type, was the Naval Operations against shore fortifications. When the Germans had occupied the Belgian Coast, it became evident that the Navy must be prepared to undertake operations against that coast, unless the Germans were to be permitted to remain in undisturbed possession, allowing them an extremely undesirable freedom of action by using the ports as bases for submarines and destroyer activities. To meet this condition and the possibility of similar conditions arising elsewhere in the vast theatre of the war, the British very early put in hand a number

of modernized monitors, which repeated the well-known characteristics of the early American vessels of this class; that is, slow speed, the heaviest guns, armor protection, low freeboard, and small size, but added to these a modern and efficient form of torpedo protection; the last named really forms the *sine qua non* of the modern monitor, for it must of necessity operate off hostile coasts and by its slow speed is peculiarly liable to successful attack by submarines. These monitors at intervals throughout the war carried out a series of very interesting bombardments on the Belgian Coast, which were accompanied by the use of such modern methods as spotting by means of aircraft and protection by means of smoke screens, produced by small fast boats accompanying them. In general, however, these operations failed to produce any decisive results, and this experience, combined with that gained through the attempts by older British and French battleships to reduce the fortifications at the Dardanelles, has gone far to confirm the opinion held prior to the war that ships cannot compete successfully with shore fortifications.

Although not productive of new types, and not, strictly speaking, exercising any influence on naval types, it is not possible to pass over the development of the transport service during the war, as its operations were on such an enormous scale. The British conveyed to and fro from the various theatres of war a total of something like 13,000,000 men, but the great bulk of these was for the short distance across the Channel. The most impressive undertakings were the combination of the American and British resources, with some help from the other Allies, in transporting to Europe nearly 2,000,000 men during the war, and the bringing of them home in a period of a little over six months by the American Navy with some help from foreign sources. The enormous undertakings demonstrated that the great passenger vessels used commercially in time of peace can be quickly and efficiently converted for use as transports, and that, therefore, the naval designer need in the future only provide for the intelligent utilization of the great mass of experience accumulated in fitting merchant vessels for this purpose. As an example of the progress made in this direction in the course of the war, can be cited the fact that when some of the large passenger vessels were first fitted for use as transports, it was thought that they had been given the maximum troop capacity. After

some months of experience, however, it was possible so to modify and perfect the arrangements that their capacity was increased in some cases as much as 50 per cent.

In reviewing the use of existing novel types during the war, one cannot omit reference to the active and important part played by certain types of auxiliaries. Colliers, tankers and supply ships were used to an enormous extent, but these are of such a purely merchant type that they require no especial note, except to remark that the few Colliers we had built as naval auxiliaries, with special handling appliances showed up exceptionally well. The purely naval types which demonstrated their efficiency and value were

GERMAN BATTLE-CRUISER *DERFFLINGER*.

Displacement	26180 tons	Speed	26.5 knots
Length	689 feet	Battery	8-12" and 14-5.9" guns
Horsepower	63000	Submerged torpedo tubes	4-19.7"

the destroyer and submarine tenders and repair ships. One or more of these vessels were stationed at each one of our principal operating bases abroad, and without them our destroyer and submarine forces would have been unable to maintain their great efficiency and high percentage of time employed in active service. Due to the shortage of shipping, it was not possible to fit out and supply an unlimited number of vessels of this type, and it soon became evident that each existing unit must be utilized to its highest degree of productivity. This led to the erection on shore at the principal bases of barracks for housing the shop operating forces, so that the ships themselves could be run 24 hours a day, using three shifts of mechanics. This development leads to

the belief that in the future in certain types of operation we may be led to provide special barrack ships for carrying and berthing sufficient personnel to utilize to the full the repair facilities provided on the vessels specially fitted for that purpose.

I have previously referred briefly to the development of the new and large type of naval vessel called an aircraft carrier. In the very early stages of the war, attempts were made to attack the principal naval bases in Germany by means of aircraft, but it was found that neither the aircraft themselves nor the commercial vessels hastily fitted up for the purpose of carrying them were sufficiently developed to permit of success in such an undertaking. I cannot in this paper take up in detail the wonderful development in aircraft during the course of the war, but the technical development resulting in increased size and speed and carrying capacity are well known. These were quickly taken advantage of by naval designers to fit them for such purely naval purposes as scouting, fire control of the heavy guns of big ships, torpedo carrying and launching, etc.

The actual offensive use of aircraft against naval vessels was little developed during the war. Perhaps the most prominent case was that of the *Goeben* which was ashore near the Dardanelles, and for six days exposed to aircraft attack, it being stated that some 217 bombs were dropped against her. There is no doubt that there will be a great development of aircraft for naval use as a result of the war experience, and some enthusiasts have visions of navies of the air rendering obsolete the navies of the ocean.

The United States Navy, which has in its own hands the development and control of its aircraft for use over the water, should take the lead in any air naval development; but there is no doubt that, step by step with the air offensive, there will be developed a defensive. The defensive, moreover, will not be passive. We have seen in the late war how the light craft, destroyers, etc., on one side met and countered the attacks of similar craft on the other side. Had either side been deprived of its light craft, it would have been at a most serious disadvantage. Similarly, developments in the air will undoubtedly be along the line of defending the capital ship by auxiliary and offensive aircraft. The big ship which must be protected from projectiles of a ton weight falling at angles of 30 degrees, fired from ships

almost out of sight below the horizon, is not yet in serious danger from bombs carried by present-day aircraft, with chances of hitting small indeed.

At the moment it appears that the torpedo plane is the most promising development; its weapon of attack is the torpedo which the capital ship must already be prepared to defend itself from, whether fired by a surface vessel or a submarine. A torpedo from a ship in the air is no more deadly than from a submarine under the surface. It seems probable that aircraft will sooner become dangerous to destroyers and the light vessels generally than to the large ships of the line. The former are more vulnerable and will be less able to protect themselves.

Even these early developments of naval uses for aircraft made it evident that they could not efficiently perform such functions with the fleet unless they could be carried with the fleet, not only on long cruises but actually in battle, with the result that special types of ships have appeared to fill this requirement. The first essential of this type is that it should be capable not only of launching aeroplanes but also of receiving them back after the accomplishment of their mission. With the present development of aeroplanes and seaplanes, the only practicable method of providing the latter requirement is the provision of an enormously large and absolutely clear deck upon which the planes can light and be brought to rest. The next requirement is that such a vessel shall have a speed sufficient to permit it to keep up with the main battle fleet when it is going into action. This means a speed of 20 to 25 knots. These qualities, together with the need for sufficient space to house and care for a considerable number of planes, together with their personnel, has resulted in vessels of 10,000 to 25,000 tons displacement. To obtain a clear upper deck requires special arrangements for funnels, navigating bridges, etc., which has resulted in the only absolutely new type of naval vessels of large size and cost which has appeared as a result of the war experience.

At the other extreme among new types appearing as a result of the war, comes what have been termed coastal motor boats. These appeared more as a result of possibilities presented by modern engineering developments than as a result of the need for filling a specific naval requirement. The perfection of the gasoline motor led in the years before the war to the construction,

for sporting purposes, of very light high-speed small boats. Due to the fact that they were developed primarily for racing, they were suitable for use only in comparatively smooth water and had to be handled with extreme care. A study of their possibilities by British designers, supported by the enthusiasm of young naval officers, resulted in the production of boats of 40 to 70 feet in length and capable of speeds from 35 to 45 knots an hour, each carrying from one to three modern torpedoes, and with the hulls constructed on such scientific principles that they could go to sea in comparatively rough weather, and could be hoisted on board light cruisers or other types of naval vessels. These little boats performed splendid service off the Belgian Coast, and the tale of their operations forms one of the most exciting chapters in modern naval annals. But the most spectacular, and at the same time valuable service performed by boats of this type during the war, was the daring penetration by the Italians into a fortified Austrian harbor where they sank a battleship lying at anchor. Later, in operations against the Bolshevists, a small British flotilla penetrated to the inner harbor of Kronstadt, where they succeeded in sinking two battleships and two other large vessels.

I have several times, in the course of this paper, referred to the results experienced when war vessels of older types are subjected to attack by modern weapons. During the war there were sunk by hostile action 21 pre-Dreadnaught battleships and 27 armored cruisers; of this total of 48, 11 were sunk by gunfire and 37 by mine or torpedo, only a single explosion in nearly every case being necessary to inflict the fatal damage. It is only necessary to refer briefly to such incidents as the sinking of the British battleship *Formidable*, the three cruisers *Cressy*, *Boukir* and *Hogue*, the loss of four old battleships at the Dardanelles, the sinking of the *Gneisau* and *Scharnhorst* off the Falkland Islands, the loss of the British *Hampshire*, and the American cruiser *San Diego* as the result of striking a single mine, together with numerous other incidents of similar nature, to show that such vessels as these, most of which were commissioned within ten years immediately preceding the war, are totally incapable of withstanding the terrific effects of present-day gunfire and torpedo attack. This showing is particularly impressive when compared to the demonstrated ability, as discussed above, of the most

modern vessels to survive severe and repeated attacks. These qualities of resistance and defense can only be provided on vessels of large dimensions and displacement. The necessity for retiring these older types was well demonstrated by the fact that except for a few used for special purposes, both the British and the Germans had placed most of their older capital ships out of commission before the war had run its course.

To sum up, therefore, the experience of the war, so far as it can be grasped to date, has resulted in demands in the case of every existing type of war vessel which can only be met by increased size and cost. It has resulted in the introduction of only one new type of major importance, namely, the Aircraft Carrier. but it has introduced a number of small types which will probably survive but will not be constructed in large numbers in times of peace, as they are peculiarly adaptable to being produced quickly in large numbers after the emergency of war has arrived.

Although we must conclude that the present tendency is toward increased size and cost, one cannot overlook the fact that this very tendency, under the present financial, economic and political conditions in the world, may actually result in the long run in the disappearance from future building programs of these very types and the substitution for them of smaller and cheaper units made possible by new developments in science and engineering. To meet this condition there never was more need than at the present time of vision and imagination on the part of the fighting forces afloat and the naval designers ashore, for that nation which can develop the weapons which will render obsolete the present great ships and can substitute for them a smaller and cheaper unit capable of defeating them will win in the new era the command of the seas, which this war has shown is so all important to ultimate victory.

Potash Deposits of Alsace. (*U. S. Geological Survey, Press Bulletin No. 445.*)—Potash salts were discovered in upper Alsace, in 1904, in drilling for oil. Subsequent explorations and developments indicate that the deposits underlie an area of more than 70 square miles, and that the workable beds have a depth of about 2000 feet and range in thickness from 6 to 30 feet. The salts consist essentially of sylvinite, a mixture of sylvite and rock salt. Estimates place the quantity of potash salts in the deposit at 1,472,058,000 metric tons, which gives more than 300,000,000 tons of

potash (K_2O). The first mining shaft was completed in 1909 and production began in 1910. In 1913, 40,707 tons of potash (K_2O) was produced from this source. The German Kali Syndicate, which controlled these mines as well as those at Stassfurt, determined the proportion of potash to be produced by the Alsatian mines at about 4 per cent. of the total annual production from Germany. The main object in limiting the output was to prevent overproduction and thus a lowering of the price.

When the Armistice was signed in November, 1918, the Alsatian mines were transferred to French control and apparently were in a very bad state of repair.

On the Nature of the Heat Production in a System of Platinum Black, Alcohol, and Air. L. B. LOEB. (*Proc. National Academy of Sciences,* March, 1920.)—When a little platinum black is put into a volume of air saturated with vapor of either ethyl or methyl alcohol much heat is developed and the solid becomes incandescent. Two theories have been advanced at different times to account for this: (*a*) That it is due to the liberation of heat resulting from the adsorption; (*b*) that it is to be ascribed to the development of heat at the surface of the platinum black caused by the oxidation of the alcohol vapor.

A thermal couple was covered with platinum black. When it was put into an atmosphere of alcohol vapor and carbon dioxide, where no oxidation could take place, the temperature rose 0.36° C., due to adsorption. When the experiment was repeated with air substituted for carbon dioxide, there was a rise of 34°, almost one hundred times as much. Furthermore, the heat due to adsorption is soon all set free, while the heat development due to oxidation continues as long as alcohol and oxygen are present.

G. F. S.

Peat as a Gas Producer. (*U. S. Geological Survey, Press Bulletin No. 446.*)—Peat consumed in a properly designed gas producer yields gas of good quality and in abundant quantity in comparison with the yield from coal and also many valuable by-products. This is perhaps the most effective utilization of peat fuel for generating heat and power, because peat that is to be used in this way does not need to be so carefully prepared nor so thoroughly dried as peat that is to be consumed for domestic purposes or under steam boilers. Gas-producing plants using peat fuel are operated in England, Ireland, Germany, Sweden, Italy, and Russia, but in the United States, although experiments have been made, no gas-producing plants are operated with peat.

Automatic Telephony. (*Electrician,* March 26, 1920.)—The British Post Office has for the present ceased to develop the automatic telephone system.

THE NITROGEN INDUSTRY.*

BY

HERMAN EDWARD FISCHER, M.S.

Lieutenant Commander, U. S. Navy.

NITROGEN, itself, is an inert gas of no particular use, but nitrogenous compounds are necessary to agriculture, to refrigeration, to munitions manufacture, and to the application of chemistry in general. In the native gaseous state, it makes up about four-fifths of the atmosphere, and combined it occurs as nitrate minerals, as organic compounds, and in carboniferous deposits. Atmospheric nitrogen is of use only after it has been artificially compounded or "fixed," a proposition which the natural inertness of nitrogen renders difficult and expensive. It has five general habits of combination—that with oxygen, giving rise to nitric acid and its retinue of nitrate salts; that with hydrogen giving ammonia and the ammonium salts; that with carbon, to form cyanogen and the cyanides; that with basic elements yielding nitrides; and, organically, in the form of organic ammoniates. The only mineral deposits of consequence are those comprising the nitrate fields of northern Chile. The organic resources include all kinds of animal and vegetable refuse. Coal-tar ammonia from retort-coke and gas manufacture, along with some shale-oil ammonia, makes up practically the whole supply derived from the carboniferous sources. This range of associations, including animal, vegetable, mineral, and atmospheric sources, surpasses all established rules of resource occurrence.

The utilization of the nitrogen contained in the air is an old problem. Cavendish discovered in 1781 that by burning hydrogen in a surplus of air, water was formed which reacted nitrically. Prominent chemists such as Lavoisier, Priestley, Davy, Robert Bunsen, Boettger, and others all gave constant time and study to the same phenomena. Boettger determined the formation of nitric acid in the discharge of an electric current. In 1900 an experimental plant was erected at Niagara by two American

* Communicated by Dr. Allerton S. Cushman.

inventors, C. S. Bradley and D. R. Lovejoy, in order to burn nitrogen from the air into nitric acid by a very high electric current. The plant soon proved unremunerative and was abandoned. In 1903, the Norwegians, Birkeland and Eyde, started in Norway the new industry of producing nitric acid from the air by means of a luminous arc. This same arc process was shortly afterwards started in Austria and Italy. In 1906 the calcium cyanamid process was successfully established in Italy, and in the subsequent years preceding the war was installed in Germany, Norway, France, Switzerland, America, Austria, Japan, and Sweden. The third of the established methods of fixing nitrogen, the Haber process for the synthesis of ammonia, was brought to a successful commercial stage in Germany in 1913.

The form of nitrogenous compound is of secondary importance, since this may be modified more or less readily to suit the need, but its value is conditioned in terms of its availability in the form of nitrogen compounds. The several sources are classified industrially under three heads:

(1) Nitrogen occurring naturally in the form of marketable compounds.

(2) Nitrogen rendered available incidentally in the course of operations otherwise directed.

(3) Nitrogen whose availability is dependent on special fixation treatment.

Chile nitrate is the outstanding representative of the first class. The guano industry, or what there is left of it, and a few other odds and ends of production from organic sources belong here as well, but their combined output is so relatively small, that the Chilean industry comprises what amounts to a monopoly of the natural resources. It is not operated as such, however, but by private capital, which owns and operates the nitrate fields, paying the Chilean government a royalty or export tax amounting to about $11.20 per ton. Chile derives over 60 per cent. of its total yearly revenue from the export tax on Chile nitrate. British and Chilean interests share about equally in making up the far greater part of the capital invested. The balance is largely German and American. The total capitalization in 1909 amounted to approximately $134,000,000, representing an actual valuation of about $30,000,000. Various efforts on the part of commercial

interests involved to effect combinations for the purpose of stabilizing production have been attempted, but have not been entirely successful, and the general tendency has all along been towards overproduction.

Before the war, practically the whole of the world's requirements in respect to nitrate and nitric nitrogen were met by the exportation of nitrate of soda from Chile, and the price of the product has hitherto governed the market price of combined nitrogen. The Chilean nitrate industry is one of long standing and has been characterized by a steady rate of expansion. By the middle of the nineteenth century the exports had attained a figure of about 100,000 tons per annum, whereas the shipments from Chile in the year prior to the war (1913) amounted to over 2,400,000 tons, 70 per cent. to 80 per cent. of which was accounted for by the requirements of Germany (833,112 tons), the United States (589,187 tons), France (327,192 tons), and Belgium (318,515 tons) alone. From 1870 to 1917 Chile has produced 55,800,000 tons of saltpeter. Experts, such as Adolf Frank and Birkeland, do not believe that this supply can last for more than thirty to forty years.

The Chilean nitrate fields lie in the arid valley basin to the east of the lofty coast range and just south of the present Peruvian boundary line. They do not occur as a single expansive area of deposition, but as deposits scattered here and there along the desert land at the bases of the mountain slopes. The formation consists of a conglomerate or breccia of rock material from the adjacent slopes, cemented with a mixture of soluble salts in which sodium chloride is the dominant member with sodium nitrate ranking second. This formation, called caliche, lies for the most part just below the surface of the ground and varies from a few feet to many feet in thickness. Only in scattered patches is the caliche high enough in content of sodium nitrate to warrant treatment. These patches are sought out and excavated, and the picked ore is loaded into carts which haul it to the extraction plant for treatment. Here the soluble salts as a whole, are extracted in solution, and the nitrate in turn is segregated from the other salts by crystallization. Aside from haulage, hand labor is used throughout.

Due to the crude operations used in treating the caliche, the cost of production is correspondingly high, amounting to around

$25 to $30 per ton at seaboard, inclusive of the $11 export tax. The caliche regarded as worth treating contains not less than 10 per cent. sodium nitrate and ranges up to 25 per cent. and over, with an average of about 18 per cent. The product marketed is of two general grades, the ordinary listed as 95 per cent. nitrate, and the refined, a guaranteed 96 per cent. nitrate low in sodium chloride. The nitrate is marketed largely through commission houses. The American situation is mostly in the hands of three companies, W. R. Grace and Company, E. I. du Pont de Nemours Powder Company, and Wessel, Duval and Company.

To the class of by-product compounds belong, with the few exceptions noted above, the nitrogenous products of organic derivation as a whole, and those from carboniferous sources such as coal and oil shale. From the former source comes a mass of organic refuse resulting from activities dealing with animal, vegetable, and fish products, and carrying nitrogen in the form of organic ammoniates, commonly left as such for use in agriculture. From the latter, the nitrogen recovered is all chemical nitrogen in the form of ammonia and ammonium salts, mostly ammonium sulphate, and is available in all capacities.

The organic production is impossible of definite analysis from any angle. The lack of systematically compiled records and back of that the miscellaneous largely decentralized character of the output, along with the fact that the producing costs are for the most part, indistinguishable, leaves altogether too much to the imagination. Much of the supply is derived from connections of sanitation, especially of local sanitation, such as the rural practice for which there is no measure whatever. Another big source of supply is from tankage, the refuse from animal rendering plants. Also the issue is lost here in the scattering of the production, the indefiniteness of composition, and the fact that not all of the product is used as a source of nitrogen, some of it going into the preparation of animal food. The same is true of cotton-seed meal and various other less prominent forms of organic waste resulting from industrial activities. Fish-scrap and slaughter-house refuse from meat packing also contribute prominently and at the same time rather more definitely to the supply of agricultural nitrogen. Even here adequate figures are not available.

Aside from the conversion of organic ammoniates, which is practiced on a large scale only in a few instances, notably that of

the Paris system of sewage disposal, four general types of industrial operation figure more or less in the production of by-product ammonia. They include coal distillation, bone carbonization, oil-shale distillation, and blast-furnace operations. The American production, however, is all derived from the first two types. Both the others are active producers abroad, especially in Scotland, but neither of them has as yet obtained a foothold in this country. The American recovery in connection with bone carbonization is of minor consequence. Practically the whole supply comes from gas works and by-product coking operations.

The growth of ammonia production from by-product coke has been extremely rapid in this country and is still on the increase. The enlargement of by-product coke production is shown by the following table, which includes solely the coke industry and not coke from gas works, etc.:

	1918—Per cent.	1919—Per cent.
By-product	44	54
Bee-hive	56	46

The installation of the by-product coke process means a larger supply not only of ammonia but also of benzol, toluol, phenol, naphthalene, and other products absolutely essential for munitions purposes and required in time of peace for the dye-stuffs industry. The use of the by-product coke process also means the production of large quantities of gas for power purposes. If the destructive distillation of coal is conducted in special producer-gas ovens, the output of ammonia can be increased five to six fold and power comparable with hydroelectric power can be obtained at the same time.

That bituminous coal used should be treated in by-product ovens is recognized the world over. It is becoming increasingly practicable to do this, and the use of coke for domestic purposes, as well as for the production of iron and steel, is rapidly increasing. The general use of coke instead of coal throughout a country does away with the smoke nuisance and all of its accompanying loss to property, and if such were the conditions in this country, it would produce, besides other by-products, approximately 1,000,000 tons of ammonia alone. The day is far off before this highly desirable result will be reached, but it should none the less be striven for.

The organic nitrogen recovered in all of the various by-product connections taken together probably constitutes 40 per cent. to 50 per cent. of the total supply. Coal-product ammonia in this country adds another 12 per cent. to 15 per cent. Therefore, over half of our supply is of by-product derivation. The domestic output of the United States is supplemented in the case of the organic form by considerable importations from South America, and, until interfered with by the war, small amounts of ammonium sulphate were imported annually from Europe. Essentially, however, the by-product supply is of domestic origin.

The industrial output of this country is built up as a sequence to industrial concentration. This is evidenced all down the line, especially in the output of coke-oven ammonia from the steel industry, and in that of organic ammoniates from the meat-packing industry. It is this influence of coördinated industrial concentration, along with the call for the major operations, that controls the supply of by-product nitrogen. Therefore, the development and handling of the industrial output comes naturally to be largely in the hands of trade combinations. Thus, the coal-product ammonia situation is largely at the disposal of the Barrett Company, the tankage and other animal product ammoniates gather for disposal at the hands of the packing interests, and the nitrogenous fertilizers from cotton seed are for the most part prepared and marketed by interests subsidiary to the Cotton Oil Company.

The manufacturing interests of this country which are involved are concerned primarily in the manufacture of other than nitrogen products. The by-product nitrogen recovered has to compete for its market against what comes from the other two sources of supply, and its price goes just low enough to enable it to do so. The limits set in the incidental character of the output leave no special incentive to carry the price competition further. Whatever additional latitude of advantage as to cost of production it possesses goes not to promoting a further reduction in the price of nitrogen but to lowering costs with reference to the major item of production. Gas-house ammonia, for example, does not affect the nitrogen market so much as it does the cost of gas, and the organic ammoniates recovered in connection with meat packing have not lowered fertilizer costs so much as they have kept down the cost of meat to the consumer.

Thus, the by-product class of supply, though the leading one in the point of magnitude, and by far the cheapest to produce, has little to do with determining the price of nitrogen. The selling price of by-product nitrogen is determined by the price the product from competing sources brings. In this country, it is controlled by the price of Chile nitrate, and not, as commonly imputed, by the trade combinations that develop and handle the output.

The arc fixation process was the first commercial process to be developed for the fixation of nitrogen. It is installed in southern Norway, employing 250,000 kilowatts of electricity developed from the cheapest large installation of hydroelectric power in the world. This is the only large installation of the arc process, but small installations of an experimental nature have been put up in other countries.

In the arc process, nitric acid is produced by the direct combination of the oxygen and the nitrogen of the air to form a dilute gaseous mixture of nitric oxides with air. The nitric oxide is converted into nitric dioxide, and is absorbed in water in immense granite towers to form nitric acid. The method is one of the most inefficient known as regards production in relation to power consumed. Nevertheless, on account of the very cheap horsepower available in Norway—$2 to $5 per horsepower year—and the fact that the raw materials cost nothing and are always at hand, nitric acid can there be produced by the arc process at a cost less than by any other commercial process.

Efforts to introduce the arc process outside of Norway have resulted unsatisfactorily, and it has made relatively little headway. The reason for this is two-fold. So far, its use of power has proven uneconomical, and its product unsatisfactory. The former of these two objections depends on its force on the demand for power, but the latter is more decisive. The immediate end product is nitric acid, which is a 30 per cent. to 35 per cent. acid, as against 50 per cent. to 55 per cent. acid obtained by other processes, and is both difficult to transport and limited as to use. To be put in shape for agricultural use it must be neutralized in the form of a nitrate salt. Limestone is the only cheap neutralizing agent. This gives a salt, calcium nitrate, which absorbs moisture, cakes, and is thus unsuited for agricultural uses in many countries. The Nitrogen Products Company, a small plant near Tacoma, Washington, working on off-peak power at $10

per horsepower year, aims to overcome this difficulty of an unsuitable fertilizer by turning out its arc product in the form of sodium nitrite.

By the Haber process, nitrogen from the air and hydrogen obtained from water are directly combined to form ammonia under the influence of a catalyzer. The production and purification of the hydrogen made by the reducing action of either coal or iron upon steam involves one of the chief items of cost in this process. The fact that the combination of nitrogen and hydrogen takes place at temperatures about 500° C. and at pressures of 100 to 200 atmospheres involves some danger and many other technical difficulties which have been overcome in Germany by the Badische Company, which owns the Haber plants and process. The technical control of the Haber process is of very great importance and requires a high degree of training and skill. This process was first commercially installed in Germany in 1913 with a plant capacity of 7500 tons of ammonia or 30,000 tons of ammonium sulphate, and in 1918 the output by this process was 265,000 tons of ammonia or 1,060,000 tons of ammonium sulphate.

As installed in the Haber plant at Appau, Germany, the hydrogen is obtained from water-gas manufacture. The average percentage composition of the gas by volume is: hydrogen, 49 per cent.; carbon monoxide, 43 per cent.; nitrogen, 5 per cent.; and carbon dioxide, 3 per cent. The proportion of nitrogen is increased by mixing in the generator gas of the following composition: Nitrogen, 63 per cent.; carbon monoxide, 24 per cent.; hydrogen, 6 per cent.; carbon dioxide, 5 per cent; and methane, 2 per cent. The carbon monoxide in the gas is converted to carbon dioxide and at the same time a further supply of hydrogen is added by mixing the gas with steam at a temperature of 400° to 500° C. in the presence of a catalyst, which is principally iron oxide with a very small percentage of other oxides, such as chronium oxide. The reaction is:

$$CO + H_2O = CO_2 + H_2 + 10 \text{ calories}$$

A slight excess of steam is required, but too great an excess must be avoided to prevent lowering of the temperature. The carbon dioxide in the gas is now eliminated by compression at 20 kg.

per sq. cm. in contact with water. Any residual carbon monoxide or dioxide remaining after this treatment is eliminated by copper formate or copper chloride under a pressure of 200 kg. per sq. cm. The proportion of nitrogen to hydrogen is kept below 1 to 3 until just before reaching the ammonia catalyst. Then the required amount is added from a liquid air machine. Methane is not a poison for ammonia catalysts but practically all the other hydocarbons are. The synthesis takes place in autoclaves at a temperature of 400° to 600° C. and at a pressure of about 200 atmospheres. At the start of the operation 2 per cent. to 6 per cent. of oxygen is added and the action begun by an electric spark. The gas after catalysis contains about 6 per cent. ammonia. This ammonia is absorbed by water, a 20 per cent. solution being obtained. The unconverted nitrogen and hydrogen are returned to the autoclaves for repetition of the cycle. The actual yield is 70 per cent. to 90 per cent. of the calculated.

The ammonia produced by the Haber process is in a water-free liquid condition ready for immediate oxidation without purification. Reliable information from Germany indicates that pure anhydrous ammonia can be produced in liquid condition for about four cents per pound. It is the cheapest process for the production of synthetic ammonia, and has the lowest power requirement of any of the nitrogen fixation processes, as shown by the following table:

Fixation Process	K W Hours—Per KG. of Nitrogen Fixed
Arc process	73.7
Calcium cyanamid process	16.5–19.5
Haber process	3.6
Hausser process	8.9
Serpek process	10.0–12.0

Another great advantage of this process is that its product is easily available for transportation and for fertilizer.

An adaptation (lower pressures) of the Haber process to American conditions was worked out by the General Chemical Company, and a plant with a rated capacity of 60,000 pounds of anhydrous ammonia per day was projected at Sheffield, Alabama, at the instance of the Government. The plant was completed, but before it could be tuned up for actual production the war ended.

The cyanamid process has been developed in many parts of Europe, but in the western hemisphere only at Niagara Falls,

Ontario, Canada. It requires cheap power for its successful operation and has obtained its greatest development owing to the fact that it requires only about one-fifth the horsepower per ton of fixed nitrogen per year that is required by the arc process. The Niagara Falls plant is now operating under a special contract with the Canadian government by which it is able to obtain power at the rate of $12 per horsepower year. This plant draws heavily on power in the preparation of the necessary carbide, and it is not believed that this plant will be able to continue operations upon the expiration of its present contract with the Canadian government as it will not be able to renew same at so low a figure.

The cyanamid process involves: First, the production of calcium carbide in a large electric furnace from lime and coke or anthracite coal; and second, the fine grinding of this calcium carbide out of contact with air, and the heating of a portion of the ground mass to a red heat to start the absorption of the nitrogen which is then added, as long as it is taken up by the carbide, to form cyanamid. The cyanamid is in turn ground and given a special treatment to remove acetylene gas in order to avoid explosions later. The cyanamid, mixed with sodium carbonate and lime, is then treated with steam in large autoclaves to convert the nitrogen of the cyanamid into ammonia gas. The process involves a number of steps and is somewhat complicated:

$$CaO + 3C = CaC_2 + CO$$
$$CaC_2 + N_2 = CaCN_2 + C$$
$$CaCN_2 + 3H_2O = 2NH_3 + CaCO_3$$

Under the stress of the wartime demand for nitrogen, this Government contracted for the erection of three plants, one at Muscle Shoals, Ala., one near Toledo, Ohio, and one near Cincinnati, Ohio, with a total rated capacity amounting to 220,000 tons of ammonium nitrate per year. The work on all three plants was well under way, but none had reached the producing stage at the time of the signing of the armistice.

The cyanide process of fixation is being experimented with, but has not been developed commercially. Nitrogen in passing through a red-hot mixture of finely divided sodium carbonate, coke, and iron, reacts with the sodium and carbon to give sodium cyanide. The reaction takes place readily. The sodium car-

bonate can be recovered to be used over again, and the iron can also be repeatedly used in the process.

The Government erected a small plant with a rated daily capacity of ten tons of sodium cyanide at Saltville, Virginia, and it had just reached the producing stage when the armistice was signed. The cyanide process, as installed in this plant, was divided into three stages: (1) the mechanical preparation of the material treated in the retorts; (2) the treatment of the briquetted soda ash-iron-coke mixture with nitrogen at 1000° C.; and (3) the extracting of the cyanide as sodium cyanide from the cyanized briquettes produced in the preceding stage of the process. The barren briquettes, after recovery of the cyanide, were returned to the mechanical preparation building, where they were reground, brought back to their original composition, and remade. The cost of making cyanide at this plant, as operated with its military personnel and post organization, was roughly 20 cents per pound, which price included all charges except royalties and profits. However, this cost would have been materially lowered by constant operation at capacity.

The only process of any prominence aiming to fix nitrogen in the nitride form is one developed by the Aluminum Company of America. This has for its working principle the fact that a mixture of alumina and carbon highly heated will absorb nitrogen by reacting to give aluminum nitride. The nitride, when heated with caustic soda, gives its end product in the form of pure ammonia. The greatest difficulty encountered in applying this process commercially seems to be that of providing a furnace capable of standing the temperature requirements. This process has not succeeded in making good industrially.

Atmospheric nitrogen and oxygen combine to a limited extent when the gases are heated to a sufficiently high temperature, and the Hausser process relies upon the explosion of a combustible gas and air, with or without enriching oxygen, in a closed vessel for bringing about the combination. The exhaust gases from the explosion apparatus contain a small percentage of oxides of nitrogen, which are recovered in the form of dilute nitric acid by absorption in water. This process has been only partly developed and is still being experimented with.

The combustion processes have a close analogy with the Hausser process, the aim in each case being to effect the oxidation of

atmospheric nitrogen by direct thermal action. The methods, of which those proposed by Bender are the best known, involve the combustion of fuel gases, such as coal gas, water gas, or natural methane gas, under conditions whereby the temperature is notably augmented, the products of combustion being rapidly cooled in order to conserve, as far as possible, the small percentage of nitric oxide that is formed. The latter is recovered in the form of dilute nitric acid, as in the case of the arc process. Combustion processes present some attractions, owing to the comparative simplicity and inexpensive character of the plant required, and if successfully developed would have an important bearing upon nitrogen fixation in countries possessing abundant supplies of coal.

All processes for the synthetic production of nitric acid, except the arc, Hausser, and combustion processes, involve the oxidation of ammonia. The processes commercially in use involve the direct oxidation of ammonia gas in the presence of air in contact with metallic platinum. By the oxidation of ammonia, nitric oxide gases are obtained of much higher concentration than those produced by the arc and similar processes. Accordingly, much less tower space is necessary for their absorption and much stronger acids can be directly obtained by concentration. An acid of 50 per cent. to 55 per cent. strength is easily obtained directly from the towers, and the concentration therof is a simple matter.

The Frank Caro process, used in Germany, involves passing mixtures of ammonia and air through electrically-heated platinum nets of 80 to 100 mesh. The platinum is heated to a dull red heat and serves as a catalytic agent under whose influence the ammonia, instead of burning to nitrogen and water, as normally would be the case, causes the nitrogen to form nitric oxide.

In the Kaiser process, also used in Germany, the air is heated before its mixture with the ammonia, and under these conditions no electric heating of the platinum net is necessary.

The Landis process passes the gas downward through the net instead of upward, as in the Frank Caro process, and cools the gases before they are allowed to come in contact with the net, instead of heating them, as is done in the Kaiser process.

The details of the preparation of the catalyzer used in the Ostwald-Barton process are kept secret, but it is known to have a very small cross-section and is placed at the end of a 60 mm.

tube, so that the products of combustion passing through the tube heat the mixed ammonia and air by radiation as they approach the catalyzer. By this means no external heat is necessary. The reaction when once started continues without interruption for weeks. It is simply necessary, by means of blowers, to force the mixture of ammonia and air through the catalyzer.

The process developed by the General Chemical Company in collaboration with the U. S. Bureau of Mines takes advantage of the fact that the action is exothermic. In this modified process no outside heat whatsoever is required after the action is once started.

A general idea of the relationship of the non-synthetic and synthetic processes from the point of view of the manufacture of particular nitrogenous products is afforded by the following table, which summarizes the primary and secondary products obtainable by the various methods of recovering or fixing nitrogen. Although everyone of these processes is capable of yielding a solid nitrogenous fertilizer, such as ammonium sulphate, calcium cyanamid, or a nitrate, either as a primary or as a secondary product, it is important to note that, of the nitrogen fixation processes, only one, namely, the calcium cyanamid process, yields a fertilizer directly as a primary product.

NITROGEN RECOVERY AND FIXATION PROCESSES.

Primary and Secondary Products.

Processes.	Primary Products.	Secondary Products.
Recovery Processes:		
By-product ammonia processes.	Crude ammonia liquor or ammonium sulphate (according to system of recovery adopted).	Other ammonium salts.
Retort or Chile nitrate processes.	Nitric acid-dilute (65 per cent.) or concentrated (90–96 per cent.), according to method of operation.	Nitrates, such as ammonium nitrate.
Fixation Processes:		
Arc process.	Oxides of nitrogen normally recovered as dilute (30–40 per cent.) nitric acid.	Concentrated (93–95 per cent.) nitric acid, or nitrates such as ammonium or calcium

Processes.	Primary Products.	Secondary Products.
Calcium cyanamid process.	Calcium cyanamid.	nitrate. Ammonia or ammonium sulphate, nitrate of urea, guanidine, and other organic products.
Haber process.	Ammonia liquor.	Ammonium sulphate or other ammonium salts.
Cyanide processes.	Crude sodium, barium, or other metallic cyanides.	Finished cyanides, or ammonia, or ammonium sulphate.
Hausser and Bender processes.	Oxides of nitrogen, normally recovered as dilute (30 per cent.) nitric acid.	Concentrated (93–96 per cent.) nitric acid, or nitrates such as ammonium or calcium nitrate.
Serpek process.	Crude or pure aluminum nitride.	Ammonia liquor or ammonium sulphate.
Conversion Process:		
Ammonia oxidation process.	Oxides of nitrogen, normally recovered as dilute (50–53 per cent.) nitric acid or alternatively as metallic nitrates.	Concentrated (93–96 per cent.) nitric acid or nitrates such as ammonium or calcium sulphate.

At the present time there is no significant production of synthetic nitrates in Japan, although it is known that the Japanese chemical industry is interested in the question and that it is undergoing rapid development comparable to our own. There are several small cyanamid plants in Japan, but their production is not large. Japanese interests are believed to be contemplating the erection of a plant or plants to produce synthetic nitrates using the process of the General Chemical Company or something similar.

In England, Brunner Mond and Company, Ltd., operating the Solvay soda plants in that country, have arranged to take over the incomplete Haber plant started by the government, and will operate the Haber process in addition to their ammonia soda business. Great Britain is at present taking vigorous steps to establish domestic fixed nitrogen industries, according to plans providing for a production in excess of domestic peace requirements.

Much interest is being aroused in France in the production

of synthetic nitrogenous products. The new processes of M. G. Claude are being tested with great success at experimental works near Montereau. He has succeeded in applying pressures of 1000 atmospheres and more in the synthetic production of ammonia. Hitherto this has been done only in Germany, but M. Claude has surpassed the German scientists, in that under the new conditions the combination of hydrogen and nitrogen takes place with such intensity that a very small apparatus is capable of a considerable output. Whereas one can get only 0.33 grams of ammonia per catalytic gram by the Haber process, M. Claude gets 10 grams.

Patent rights for the Haber process in France have been acquired by the firm Kuhlmann in conjunction with the Colliery companies at Lens and the Banque de Paris. The construction of large factories for the production of synthetic ammonia, nitric acid, etc., is about to be taken in hand, and the capital to be invested in these undertakings will amount to fifty million francs.

Italy has several cyanamid plants with a total production, however, insufficient to meet the domestic demand. Like Great Britain and France, it is putting forth every effort to increase its fixed nitrogen industries.

The total possible yearly output from existing plants in Germany is estimated at 500,000 tons of nitrogen, 60 per cent. of which can be produced by the Haber-Bosch process and 20 per cent. each by the cyanamid works and the gas and coke industries. In October, 1918, the industry had so far recovered that 25,000 tons of nitrogen were being delivered per month when further progress was interrupted by the revolution. The 18 per cent. of the total nitrogen supplies contributed by gas works before the war has now sunk to 5 per cent., but these will continue to manufacture ammonium sulphate in order to make full use of their plants. The demand for artificial nitrogenous fertilizers in Germany is very great, since all farmers there are now convinced of their importance and value. With the coöperation of the government, the five leading producers of nitrogenous fertilizers have formed a syndicate, the object of which is not to make large profits, but to increase output, to exercise control over prices, and to secure fair distribution. Attached to this syndicate is a committee on which both producers and consumers are represented. By mutual concessions and adjustments between these it is be-

lieved that the German farmer will be able to obtain his nitrogenous fertilizers three times cheaper than if he imported them from abroad.

During the past six months the nitrate exports from Chile have dropped considerably, due chiefly to labor strikes and the unsettled conditions in that country. The government is yet undecided as to what stand to take as regards this industry; that is, whether to lower the export tax on Chile nitrate, from which it receives its principal revenue, and thereby give its nitrate a better chance of competing with the synthetic nitrate on the market from Germany, principally, and other countries, or to maintain the high export tax and take a chance on being able to keep its sales of Chile nitrate fairly large in the face of competition of foreign synthetic nitrates.

If the Kahn bill, now pending in Congress, is passed, the U. S. Army contemplates running its cyanamid plant at Muscle Shoals, Alabama, and is at present engaged in considerable research work in connection with the various products obtainable. This plant is designed for a yearly output of 220,000 tons of cyanamid or 35,000 tons of ammonia. The original cost of this plant was $70,000,000 and $12,000,000 are yet needed, $2,000,000 for necessary repairs and alterations, and $10,000,000 as an operating fund. The Army authorities plan to run one-third of the plant, four furnaces, at a profit on the money still to be invested ($12,000,000). Three of the four furnaces are to be used in making ammonium sulphate, and the fourth in mixed compounds. They also hope to be able to separate out and recover the 15 per cent. graphite and 6 per cent. sodium hydroxide contained in the autoclave smudge. In the way of fertilizers, they are at present experimenting with compounds of ammonium sulphate and ammonium nitrate, and an excellent non-hygroscopic compound consisting of sodium chloride, potassium chloride, and ammonium nitrate.

The formation of the Atmospheric Nitrogen Corporation, capitalized at $5,000,000, and combining the Solvay Process Company with the General Chemical Company in the matter of nitrogen fixation, has just been announced. This new corporation plans to operate the Haber process in this country in connection with its soda industry. As the establishment of an independent, self-supporting fixed nitrogen industry in America for

the increase of crops in time of peace and as a preparedness measure for war is greatly to be desired, this announcement is of extreme economic importance.

In the Haber process, the chief item of expense is the cost and purification of the hydrogen required for the reaction:

$$N_2 + 3H_2 = 2NH_3$$

The cheapest known method of producing hydrogen in quantity for this process and the one used at Appau is shown by the reactions:

$$C + H_2O = CO + H_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$
$$(CO + H_2) + H_2O = CO_2 + 2H_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Eleven tons of carbon dioxide are produced for every ton of hydrogen set free. For a long time this carbon dioxide was considered as a useless waste product, and such appears to have been the case in Germany until early in 1918. Someone, however, finally remembered that in the Solvay soda process thousands of tons of carbon dioxide are used each year and many hundred thousand tons of limestone burned for this specific purpose. A short study at once made plain that the ammonia industry and the soda industry for most civilized countries is or should be of the same order of magnitude, and a further interesting interdependence was at once brought out.

The Solvay soda process is usually considered as involving the following reactions:

$$CaCO_3 + C\ (+ O_2) = CaO + 2CO_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$
$$NaCl + H_2O + CO_2 + NH_3 = NaHCO_3 + NH_4Cl \quad \ldots \quad (4)$$
$$2NaHCO_3 = Na_2CO_3 + CO_2 + H_2O \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$
$$2NH_4Cl + CaO = CaCl_2 + 2NH_3 + H_2O \quad \ldots\ldots\ldots\ldots \quad (6)$$

By adding the rich carbon dioxide from (5) to the much leaner gas from (3), a carbon dioxide of around 55 per cent. carbon dioxide is obtained for use in (4). The waste carbon dioxide from the Haber process is much purer and varies from about 75 per cent., if nitrogen is mixed with the water gas, to approximately 90 per cent. if it is not. One of the great drawbacks of the Solvay process is the waste of ammonia in recovery (6), and of lime and chlorine, as calcium chloride, the latter being a waste nuisance that is present at every ammonia soda plant. At the same time, one of the problems of any plant fixing nitrogen

as ammonia is to produce the ammonia in a form suitable for application to the soil. This is commonly done by neutralizing with sulphuric acid to form the sulphate. Any neutral, fixed, and nonhygroscopic salt of ammonia, of which there are few, would probably do as well. It has been shown by Georges Ville and others that ammonium chloride, which is a more concentrated nitrogen product than the sulphate and meets the other requirements also, is equal to sulphate as a fertilizer.

Accordingly, a synthetic ammonia plant and a Solvay soda plant supplement each other perfectly when the above method of producing hydrogen is utilized. If the waste carbon dioxide, together with the ammonia, is passed into brine, the products obtained at once are sodium bicarbonate and ammonium chloride, the one ready for sale or conversion into soda ash, the second ready for the fertilizer markets. For the recovery of ammonium chloride in the solid form, suitable for fertilizers, it seems that it will not be necessary to resort to evaporation, for Claude states that in collaboration with Mittau he has worked out an adaptation of the method of Schreib for alternative precipitation of the sodium bicarbonate and of the ammonium chloride, depending upon the very slight solubility of the ammonium chloride in cold solutions of neutral ammonium carbonate of appropriate concentration.

By the coördination of these two processes to meet America's needs for fixed nitrogen, there will result lower installation costs for both processes, the saving of several hundred thousand tons of sulphuric acid, several hundred thousand tons of lime, several thousand tons of coke, and the elimination of a waste product that has always been considered a nuisance. The saving may be credited to either product at will.

One wartime achievement, the oxidation of ammonia, stands out as affording a worth that is unmistakably clear. The nitrogen situation has two aspects, the military and the agricultural. The military focus is on nitric acid, and the readiest means of affording a supply, while the agricultural focus is on ammonium compounds, or their equivalent in neutral nitrogen salts, and the most economical means of supply. Here is the parting of the ways to expediency. Ammonia oxidation gives a means of supplying the military requirement from the direct line of agricultural efficiency. From the strictly military viewpoint, it has the

objection of being a roundabout procedure. The direct line of military efficiency, however, has no peace-time function, and consequently cannot be maintained in time of peace in trim for war, but must, instead, be built up expressly to meet wartime exigencies. We have had one illustration of what this means in the way of time and money, and this one ought to suffice. The agricultural channel once built upon a basis of economic efficiency is open at all times. It is then only required to keep an eye on the emergency needs in the way of oxidation equipment, a very easy matter. Therefore, instead of the uncertain procedure of trusting to luck which characterized our prewar attitude toward nitrogen on the one hand, or of attempting the impossible in the way of maintaining a military program of industrial procedure in time of peace on the other, all that is needed is a constructive program devoted expressly to the interests of economic efficiency.

At present there is no import duty on nitrogen and there probably will not be any, for nitrogen is an important cog in the mechanism of food supply, and the peace-time emphasis is primarily on cheapness and only secondarily on the point of origin. Accordingly, looking ahead, the American market conditions, once world trade is fully restored, are due to reflect the world conditions. The sudden ending of the war with its consequent calling off of the military requirement, which had been building up steadily since even before the outbreak of hostilities in 1914, left the world with a producing capacity 30 per cent. to 40 per cent. above normal. This apparent overproduction, amounting to some half million tons of nitrogen, is, however, not proving real, due chiefly to the great food shortage. On the other hand, there is the producing capacity of the plants not yet in operation to be taken into consideration. Whatever may be the capacity of agriculture to absorb from the total production, it is not believed that it will take up the full amount immediately or without special inducement. The inference follows that price and production will come down to stimulate and coördinate with the increase in demand. At any rate, there will no doubt be a contest of competition between the three types of industrial source, the natural, the by-product, and the fixation types.

With the development of fixation, there have been a lot of unfounded statements to the effect that the day of Chile nitrate is passing. However, the high cost of producing Chile nitrate

(around $30 a ton) is largely due to the unsystematized and crude methods of operations, the high export tax, and overcapitalization, all of which are variable factors and are susceptible of indefinite modification in keeping with the need. Chile nitrate has never made any pretense of competing against by-product nitrogen with its advantages in the way of low incidental producing costs and proximity to the market. The discrepancy between the by-product supply and the total demand for nitrogen has all along comprised the field of opportunity opening to Chile nitrate. In this, its only noteworthy competitor, is the fixation industry.

The fixation sources are impossible of analysis on a definite basis of cost, as there are too many variable factors involved. Repeated attempts have been made, but all they have served to bring out is that under certain conditions, as for instance, of power supply, and for certain express purposes one form of project has an apparent margin of advantage over another, and *vice versa* for other conditions. In some cases the solution advanced has called for some special measure of relief from industrial competition, whether natural, as in the case of the Scandinavian power supply, or political, as in the case of the American and German projects. Fixation, however, has its possibilities of development into something commercially and economically as well as politically worth while, but the existing condition of affairs is undoubtedly due for a lot of boiling down, and much that is useless is certainly due to go. The American developments have a particularly unfavorable economic setting in the prevailing scale of costs.

With reference to the organic group of compounds, the outlook for the future is as uncertain as the actual conditions of to-day. The centralized development of meat packing, of animal-rendering establishments, and of cotton ginning have given rise in their time to highly important recoveries of nitrogenous waste, but with the forward progress of developments, this usage in turn is giving way to a more advanced order. Cotton-seed as a fertilizer is giving place to a cotton-seed product industry; tankage as a fertilizer is giving place to the artificial compounding of animal food; and the horse, an important contributor of agricultural nitrogen in times past, is giving way to the automobile. Developments are on foot that lead in both

directions, and there is no telling how the balance is due to shift. Probably the best guess is that relatively at least it will be downward rather than upward.

The outlook for by-product ammonia is more definite. Ammonia is the end point of material refinement, so here the nitrogen developments hold all they get rather than going on to lose out again in a further refinement of usage as in the case of the organic group. The output has increased consistently and rapidly, owing to the transition from bee-hive to by-product coking operations, and to the progress of centralization and coördination, in other words, with reference to coke manufacture.

In general, the by-product sources are of an order such that they were not materially affected one way or the other by the war, and consequently are not being materially affected in the process of readjustment. Of special significance in connection with what lies on beyond for the by-production of nitrogen is its relationship to the progress of industrial coördination.

So far, the recovery of by-products in connection with the use of coal has been confined in the one direction of coke-making, along with the analogous procedure of gas manufacture. The development which has thus started in the coke industry will, however, not stop there. The loss of motion resulting from lack of coördination in the use of coal is just as great in other directions as in that of coke-making, and the advantages of integral usage may be expected to assert themselves. Already projects are being put through, such as furnishing gas to cities, employing by-product operations located at the mines in support of the waning natural gas supply, and integrated heat, light and power projects operating on coal with by-product recovery. Meanwhile, the motor-fuel situation is suggestive of interesting developments ahead. There is every reason to believe that the petroleum resources cannot continue to meet the growing demand; in fact, that the occasion for support is already at hand. Whatever the nature of these supporting developments, whether they take the form of a shale-oil industry or what, it seems certain they will usher in an important source of by-product nitrogen.

Germany can produce nitrates at one-half the cost of nitrates in this country which are manufactured from the imported Chilean product, and consequently, the German farmer can be supplied with fertilizers, manufactured from synthetic nitrates, at one-half

the cost to the American farmer. This advantage to Germany is, of course, stupendous. If Germany succeeds in monopolizing this industry, which she is in a position to do, barring internal disorders and revolutions, she can export nitrates at a price which will enable her to supply her farmers with fertilizers at practically no cost, or she can undercut the price of nitrogenous products to such a point that it will no longer be profitable for Chile to operate her nitrate mines. If these mines are ever abandoned, it will take years to reëstablish the normal production. If this happens, and our Government is so short-sighted as to permit a German monopoly of the nitrate industry, Germany will also indirectly control the world's production of explosives and propellants. Our fleet and army will, of course, be utterly helpless without nitrates necessary for munitions of war.

Synthetic nitrate plants should be constructed, and their success will grant assurance of our safety in times of war, and in times of peace will provide the American farmer with fertilizers at almost one-half their present cost. In event of war, our existence may be dependent upon such plants. In any event, our security would be vastly increased, the burden of obligation carried by our fleet would be greatly reduced, and its functional, effective value doubled.

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The Mass-spectra of Chemical Elements. F. W. ASTON. (*Phil. Mag.*, May, 1920.)—The Positive Ray Spectrograph is described in detail by means of which a focussed spectrum is obtained. The lines due to the joint action of a magnetic and of an electric field are located in positions which depend only on the ratio of mass to electrical charge. The following elements have been analyzed: H, He, C, N, O, Ne, Cl, A, Kr, X, Hg. Of these the first five seem to be pure, while the others are apparently made up of isotopes, varying in number from two in the case of argon to six for krypton. With the exception of hydrogen "all masses measured, allowing for multiple charges, are exactly whole numbers within the error of experiment ($o = 16$)." While there is no reason to doubt the accuracy of the measurements, it is possible to interpret them in a somewhat different manner, as, indeed, a Philadelphia investigator does in the case of the atomic weight of argon. The prevalence of whole numbers is a fact of great significance for the understanding of the structure of the atom. To explain the failure of hydrogen to have a whole number for its mass, its mass proving by measurement to be 1.008, the author reminds us that, on the electromagnetic theory of mass, the mass of an aggregate of masses is not in general equal to the sum of the component masses except when these are relatively far apart. In the nucleus of oxygen the packing of particles and electrons is close. Hence the atomic mass of the latter element is not sixteen times as great as that of hydrogen, but a little less than sixteen.

G. F. S.

New Process for Preparation of Glycerol.—During war glycerol is required in abnormally large quantities for the manufacture of munitions. Since fats and oils are the source of glycerol the supply of these foodstuffs is consequently decreased; for the fatty acids, which may be obtained as a by-product in the manufacture of glycerol, cannot be directly ingested and assimilated.

However, Arthur Lapworth and Leonore K. Pearson, of the University of Manchester, England, have devised a method for the chemical decomposition of fats with the production of glycerol and an edible by-product—the mannitol esters of the fatty acids, which are synthetic fats and oils. This research is described in the *Biochemical Journal*, 1919, xiii, 296–300. Olein, such as olive oil or stearin, is mixed with mannitol and a small amount of dry sodium ethoxide which functions as a catalyst. The mixture is distilled under reduced pressure. The distillate consists of glycerol, water, and a small amount of alcohol. The residue in the distillation vessel is a substance which possesses many of the properties of the original fat; in chemical compositions it corresponds closely to a mixture of the dioleates or distearates of mannitan and isomannide. The maximum yield of glycerol is obtained when fat and mannitol are mixed in the ratio of two molecules of the former and three molecules of the latter.

J. S. H.

Paracoumarone Resin in Varnishes.—This resin is obtained by the polymerization of the coumarone and indene in certain aromatic naphthas, and is recovered in considerable quantities as a by-product in the manufacture of these naphthas. W. W. KING, F. W. BAYARD, and F. H. RHODES (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 549–552) point out the advantages of paracoumarone resin as a varnish gum. The price of the resin is approximately equal to that of ester gum and much below that of the better grades of kauri and other imported gums. The resin may be purchased in quantity in a number of grades, which differ in color and in melting point. Since it is free from dirt and sticks, neither the resin nor the varnish require purification to remove such impurities. The resin contains no volatile ingredients which are lost during the cooking of the varnish; therefore, all the resin remains in the varnish. Since the resin is chemically inert, varnish made with it is very resistant to the action of ammonia, lye, soap, other alkalies, vinegar, fruit acids, other acids, alcohol, and alcoholic solutions.

J. S. H.

On the Relation Between Illumination and Electrical Conductivity in Selenium. A. O. RANKINE. (*Phil. Mag.*, May, 1920.)—The investigator gives a surprisingly good character to selenium cells for reliability within definite limits. "The effect of light on them is quantitatively reproducible again and again."

Contrary to the tacitly accepted idea that the change of electrical conductivity in selenium is as the square root of the intensity of the incident light it is claimed that extended experiments show the change to be proportional to the fourth root of the light intensity.

G. F. S.

GRAVITATION AND RELATIVITY.*

BY

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THERE are two classes of theories relative to gravitation: those relating to the manner of action of gravitation without regard to its cause, and those relating to the cause of gravitation. There have been many theories of both classes. Until recent years the classic Newton theory of the manner of action was accepted as complete and correct, and most theories dealt with the cause. In the consideration of the fundamental phenomena of physics the conception of a cause is not always clear. We are accustomed to explaining the more complex phenomena, let us say those of geology, for example, in terms of other simpler phenomena, chemical changes and effects of heat and mechanical forces, which while simpler are still tangible, directly perceptible phenomena. But when we attempt to find causes for these phenomena in turn, we find our conception of the meaning of the word "cause" is not always clear; for we can not indefinitely explain each thing in terms of another. In the past, when physicists attempted to find a cause for gravitation or for some other fundamental phenomenon, they were apt to suppose it produced by some mechanism or process which resembled ordinary things, and which seemed simpler merely because it was more familiar. Thus gravitational forces were thought to be produced by the impact of flying particles or by currents or waves in a material medium, while the systems thus imagined were fully as complex as gravitational action, if not more so, and required an explanation for themselves that was no easier to give than the first.

The more recent observations have rendered improbable the existence of any material medium or ether in the old meaning of the word, in space, by showing that phenomena are independent of the velocity of the system with its observer through space. The only thing remaining that might be considered simpler or more fundamental than gravitation is electricity, and it is pos-

* Communicated by the Author.

sible that gravitation and electrical phenomena are correlated phenomena, forming part of the same system, rather than that one is entirely a function of the other. Any attempt to explain such things in terms of something still more fundamental carries us into an entirely different sphere of thought, in which our ideas of cause must be reconsidered.

It will thus be seen that the majority of the older theories of the cause of gravitation are no longer worth serious consideration, and only those intended to correlate gravitation with electricity are of consequence. Even in these there has been little real success, as is indicated by the fact that no one has been able to deduce the value of the constant of gravitation from any theoretical considerations.

GRAVITATION ACCORDING TO NEWTON.

The gravitational theories which are now receiving attention are those relating to the manner of action of gravitation. Newton's theory is such a theory, and before taking up the recent theories it will be well to consider briefly Newton's theory, the evidence from which Newton deduced it, the evidence supporting it that has been obtained since Newton's time, and the reasons why we are not now entirely satisfied with it, but are considering new theories.

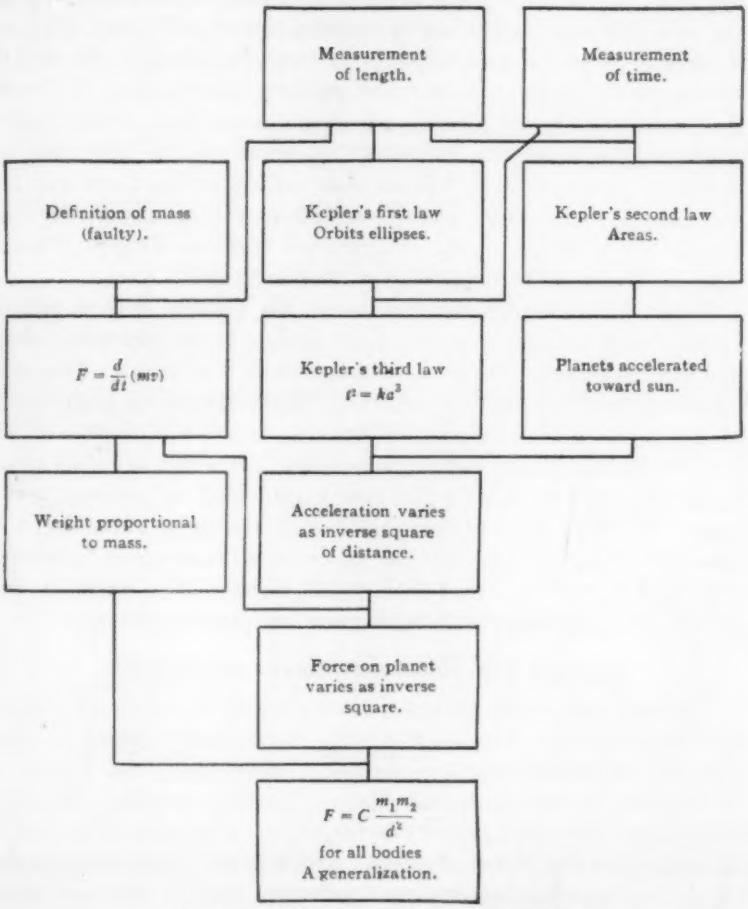
The steps by which Newton's law was deduced will be presented by means of a form of diagram which I have found very useful in the study of physical principles. The lines in the diagram indicate upon what antecedent principles each principle depends.

A complete account of the principles comprised in this diagram would, of course, include a precise statement of each, with its demonstration or the presentation of observational evidence. This would require too much time to be presented now, and only a résumé is attempted.

Kepler's first law stated that the orbits of planets are ellipses with the sun at a focus. The second stated that the line connecting the sun with a planet passes over equal areas in equal times. The third stated that the square of the period of revolution of a planet is proportional to the cube of the major axis of its orbit.

From Kepler's laws, obtained by the observation of planets, Newton was able to deduce in a rigorous manner that the accele-

ration of a planet is in the direction of the sun and varies as the inverse square of the distance. To express this in terms of force it is necessary to introduce the definition of force, which depends in turn upon that of mass. Newton's definition of mass


Measurement of length.
Measurement of time.
Definition of mass (faulty).
Kepler's first law Orbits ellipses.
Kepler's second law Areas.
$F = \frac{d}{dt}(mv)$
Kepler's third law $t^2 = ka^3$
Planets accelerated toward sun.
Weight proportional to mass.
Acceleration varies as inverse square of distance.
Force on planet varies as inverse square.
$F = C\frac{m_1 m_2}{d^2}$
for all bodies
A generalization.

GRAVITATION ACCORDING TO NEWTON.

was quite insufficient. He defined it as the product of volume and density; but density is commonly defined as the ratio of mass to volume, and as he presented no independent definition of density, he was guilty of reasoning in a circle.

His definition of force involves the assumption that the force

measured by the rate of increase of momentum of a moving object is the same for all velocities. For ordinary velocities this is very nearly true, as can be shown by the observation of falling bodies. Nevertheless, the fact should not be overlooked that the assumption that this is universally true is involved. I will not discuss now in detail the correlation of this definition and Newton's laws of motion, from Newton's point of view, but these matters will be considered later from a more modern standpoint. If, however, we accept the relation, force equals mass times acceleration, which results from the definition of force as the time rate of change of momentum, it follows that the attractive force exerted on a planet by the sun varies inversely as the square of the distance. The proportionality of attractive force or weight to mass, Newton deduced from pendulum observations.

Upon these results Newton based his general law of gravitation, which he held to apply to all bodies in the universe whatever their size, velocity, relative distance or condition. This was a generalization from observations of the behavior of bodies of a limited variety under limited conditions. It was a bold generalization, but one that has been of great value to science, and has stood for a long time as one of the best established of physical principles. We have now to compare it with the more extensive and more accurate observations that have been made since Newton's time; and even if we find that small discrepancies exist, it will still remain preëminent among human accomplishments.

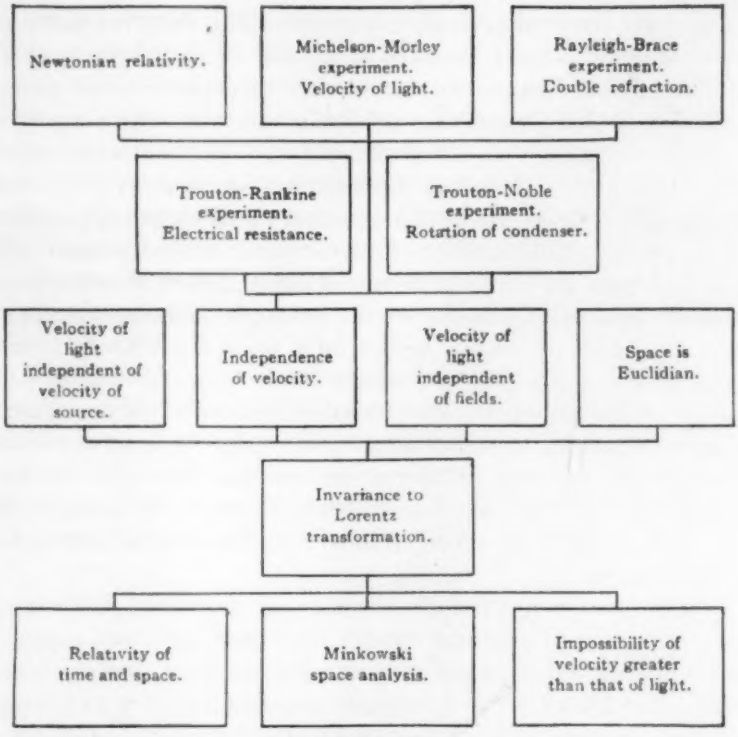
NEWTON'S LAW FROM THE MODERN STANDPOINT.

The motions of the planets nearest the sun do not exactly agree with the motions calculated by the Newtonian theory. Also, there are slight discrepancies between observation and theory in the motion of the moon and that of Encke's comet. All these effects are very small; the most important discrepancy occurs in the motion of the planet Mercury, which is the planet nearest the sun and the one having the most eccentric orbit. The perihelion of the orbit of this planet, that is, the point of the orbit that is nearest the sun, is slowly changing its angular position relative to the sun. This change is in part produced by the attraction of other planets, but after allowing for these influences a change of about 43 seconds of arc per century remains.

It has been suggested that this change may be produced by a

small planet, or a number of very small planets, revolving close to the sun. It has been held, however, that such an assumption can not entirely account for the anomalous motion of Mercury, and that of Venus, which is the next planet. Also, diligent search has been made for such planets, and none has been observed.

We have thus found astronomical evidence of inaccuracy in Newton's law. Evidence of a different character is obtained


Newtonian relativity.
Michelson-Morley experiment. Velocity of light.
Rayleigh-Brace experiment. Double refraction.
Trouton-Rankine experiment. Electrical resistance.
Trouton-Noble experiment. Rotation of condenser.
Velocity of light independent of velocity of source.
Independence of velocity.
Velocity of light independent of fields.
Space is Euclidian.
Invariance to Lorentz transformation.
Relativity of time and space.
Minkowski space analysis.
Impossibility of velocity greater than that of light.

RELATIVITY.

from the theory of relativity. On account of its bearing upon this question, and because we shall later have occasion to compare the ordinary theory of relativity with a new one of different character, a diagram is presented showing the principles upon which the theory of relativity is based, and some of those which can be deduced from it. This is not by any means intended as a complete account of this theory, but merely as a convenient summary of the more important principles.

THE OLDER THEORY OF RELATIVITY.

The development of the theory of relativity has been the result of the observation of the principle of the independence of velocity, according to which it is impossible by any means to observe or determine an absolute velocity through space; or, all physical phenomena in an isolated system as they appear to an observer within the system are independent of the velocity. There are some other physical principles very much like this; for there are some laws of physics that are applicable at all points in space, the laws that determine the manner in which a system will change with time, which connect its condition at one time, which condition we call the cause, with its condition at a subsequent time, which we call the effect. It is also true that these general laws hold true at all times. Hence we have a principle of independence of time. They are also independent of the orientation of the system in space. Hence we have a principle of independence of orientation. And we have now to consider the principle of independence of velocity. This of course applies only when the velocity is uniform and in a straight line, otherwise there is acceleration. So far as mechanical effects are concerned this principle is not new. It formed part of the mechanics of Newton. It is an every-day observation, for you in this room can not now tell me how rapidly you are moving nor in what direction, in spite of the fact that we have a velocity relative to the sun of about 1100 miles a minute.

In the past it has been held only that mechanics alone gives us no criterion of absolute velocity, but since light was supposed to be propagated by some all-pervading medium, and to travel with a constant velocity relative to this medium, it was thought that experiments with light or other electromagnetic phenomena should enable us to determine our absolute velocity through the ether. For instance, if we are moving in the same direction as a beam of light the apparent velocity of light as observed by us should be the difference between its true velocity and our own velocity, while if we measured the velocity of light moving in the direction at right angles to our motion this should give us more nearly the true velocity, and the comparison of these results should enable us to calculate our own velocity. This is essentially

the famous experiment of Michelson and Morley; but they found that the apparent velocity of light moving in different directions is the same, just as though the earth were stationary in space.

Since this experiment several other attempts have been made to observe the effects of the velocity of the earth. Thus it had been suggested by Fitzgerald and by Lorentz that the Michelson-Morley result would be accounted for if a moving body were always contracted in the direction of motion by a certain amount. The experiments of Rayleigh and Brace were for the purpose of finding whether this contraction causes an isotropic transparent body to become doubly refracting. They found no such result, and this and other experiments lead to the conclusion that although such a contraction may be apparent to a stationary observer, neither the contraction nor any other internal evidence of the velocity is apparent to an observer within the moving system.

There is other evidence supporting the principle of independence of velocity; I have given only some of the most important.

From the principle of independence of velocity we may deduce certain mathematical conditions with which general physical equations must comply. Here again there is an analogy with the more familiar principles of independence of orientation, and of position. Thus the independence of position requires that if in any general equation we make the substitutions:

$$\begin{aligned} x &= x' + a \\ y &= y' + b \\ z &= z' + c \end{aligned}$$

the new equation is of precisely the same form as the old, having merely x', y', z' where the old had x, y, z. The equation is said to be invariant to the transformation.

The principle of independence of orientation requires that general equations should be invariant to a transformation which represents a change of orientation, thus

$$\begin{aligned} x &= x' \cos\theta - y' \sin\theta \\ y &= y' \cos\theta + x' \sin\theta \\ z &= z' \end{aligned}$$

represent the case in which the change in orientation is a rotation through the angle θ about the z axis. If we apply this trans-

formation, for example, to the Laplace equation of gravitational potential,

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0,$$

we obtain

$$\frac{\partial^2 \phi}{\partial x'^2} + \frac{\partial^2 \phi}{\partial y'^2} + \frac{\partial^2 \phi}{\partial z'^2} = 0,$$

and this equation is invariant to the transformation. Now it can be proved that any differential expression involving x, y, z, and a limited number of dependent variables and their derivatives up to a specified order, if it is invariant to such transformations, is expressible as a function of a certain small number of independent differential forms, of which the Laplacian given above is an example. By the methods of the theory of invariants the number of possible independent forms or differential parameters can be determined and the forms themselves can be found. This is the basis of the ordinary three-dimensional vector analysis.

The principle of independence of velocity leads us to similar results. It requires that all general equations should be invariant to a certain transformation. If the velocity is in the direction of the x axis the transformation is

$$x = \frac{x' - \beta ct'}{\sqrt{1 - \beta^2}}, \quad y = y', \quad z = z', \quad ct = \frac{ct' - \beta x'}{\sqrt{1 - \beta^2}},$$

where c is the velocity of light, and $\beta = \frac{v}{c}$ where v is the velocity of the system. A transformation applying when the velocity is in any direction can of course be written. This transformation was first employed in an imperfect form by Lorentz in the consideration of the electrodynamics of a moving system; it is known as the Lorentz transformation. It was afterward deduced by Einstein upon the basis of certain postulates relative to the velocity of light.

From the principle of the independence of velocity, and the observations which support it, we conclude that to an observer within a system moving with uniform velocity the velocity of light is the same in all directions.

Einstein assumed also that its velocity is independent of the velocity of the source. Of this we have good observational evidence, of which I will mention only that presented by binary stars. Consider for simplicity the case in which a small star is

revolving around a larger one with the earth in the plane of the star's orbit. Suppose we observe the times at which the star reaches the two extremes of its orbit. These times are at equal intervals, but in one case the star is moving toward us while in the other it is moving away, and if the velocity of the star contributed to the velocity of the light the events would not appear to occur at equal intervals and might even be observed in the wrong order.

Einstein made a third assumption relative to the velocity of light, namely that it is independent in free space of the influence of any surrounding objects or of the electric, magnetic or gravitational fields they produce. This agreed with observation so far as observations had been made, but we shall see that the theory of gravitation which Einstein developed later is not in harmony with it.

It should be mentioned here that Einstein assumed that space is Euclidian. This assumption is made in practically all physics and is certainly not far from the truth. I mention it especially here because in some later work he considers that it is not true. The assumption is equivalent to the acceptance of the principle of Euclid that the square of the length of a straight line is equal to the sum of the squares of its projections on rectangular axes:

$$s^2 = x^2 + y^2 + z^2$$

With these conditions the required transformations are merely the relations which must exist between the coördinates employed by a stationary observer and those employed by a moving observer in order that to both of them a light wave from a point source shall appear to form a spherical wave, that is, have the same velocity in all directions.

Just as independence of orientation and position lead to the ordinary three-dimensional vector analysis, the addition of the independence of velocity leads to a set of differential parameters involving the four independent variables x, y, z and t. For the special case in which the system is stationary each of these parameters must reduce to one or more of the three-dimensional forms. For example, the wave equation:

$$\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2} - \frac{\partial^2\phi}{\partial (ct)^2} = 0$$

is invariant to the Lorentz transformation if ϕ is a scalar (as

well as to the orientation transformation) and reduces when $\frac{\partial \phi}{\partial (ct)} = 0$ to the equation of Laplace.

The equation of Laplace, which represents Newtonian attraction when ϕ is gravitational potential, is not invariant to the Lorentz transformation, and of course Newton's equation is not invariant either. Thus we have an evidence of the inaccuracy of Newton's law. We have shown in essence that if a system of bodies followed Newton's law as observed by one observer, they would not appear to follow the law as seen by an observer moving relative to the first with a uniform velocity.

Minkowski has shown that the Lorentz transformation is strictly analogous to the orientation transformation in that it represents a rotation or change of orientation in an imaginary space of which the coördinates are x, y, z, and ict, where i is the imaginary quantity $\sqrt{-1}$. As to whether you regard this four-dimensional space as real (in the physical sense, as distinguished from the mathematical) or as merely a chance mathematical analogy, you may take your choice. It will depend upon your criterion of reality, and that is more or less arbitrary. But whatever its philosophical interpretation it is extremely useful. Just as the ordinary vector analysis enables us to express general physical equations much more simply than without its use, so the four-dimensional analysis produces a further condensation, and it is not a mere abbreviation but a real simplification by the elimination of unessential framework.

It is noteworthy that the Lorentz transformation expresses the time of one observer in terms of the time and position of the other, and *vice versa*. Thus time and space are relative. From the Minkowski point of view, there is no particular direction in the four-dimensional space which must be taken as the time direction. A moving point in ordinary space corresponds to a stationary line in Minkowski space, while a stationary point corresponds to a straight line having the direction of the time axis; but the direction of the time axis appears different to observers on systems on different lines.

It may be noted that this argument does not prove that there are no independent space and time and no absolute velocity, but only that it is impossible to determine them by observation. The distinction is perhaps immaterial, but there is no objection to

anyone's continuing to imagine space and time as distinct and velocity as absolute if only he realizes that no observation can give evidence of them. However, aside from the persistence of old ways of thinking there is no more reason for this than for imagining absolute position, absolute time or absolute orientation.

The theory of relativity has taken a little more away from the already diminished prestige of the theory of an ether. I am not aware that its existence can be actually disproved by the relativity theory, although it can not be the kind of an ether it was once imagined to be.

RELATIVITY AND EVIDENCE AGAINST NEWTON'S LAW.

The theory of relativity presents evidence against the possibility of gravitational force or anything else having a velocity greater than that of light.

In a system considered as stationary suppose that some impulse or signal is sent from the point x_0 to the point x, with uniform velocity u. The time that elapses will be

$$\Delta t = t_1 - t_0 = \frac{x_1 - x_0}{u}.$$

Now consider another system moving relative to the first in the same direction with velocity v.

To an observer in the second system the interval of time would appear different. Its apparent value can be calculated by applying the Lorentz transformation for the time. The result is

$$\Delta t' = t_1' - t_0' = \frac{t_1 - \frac{v}{c^2} x_1}{\sqrt{1 - \frac{v^2}{c^2}}} - \frac{t_0 - \frac{v}{c^2} x_0}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

From this equation we can eliminate x_0, x_1, t_0, and t_1, by means of the previous equations; the result is

$$\Delta t' = \frac{1 - \frac{uv}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}} \Delta t$$

It will be noticed that if $\frac{uv}{c^2} > 1$ the two intervals of time will have opposite signs. Now v can have any value up to the velocity of

light c. For instance, electrons have been driven with velocities approaching that of light, although to do this it is necessary to impart a large amount of energy to them. Hence if $u>c$, v can be made so large that $\frac{uv}{c^2}>1$. In this case an observer on the moving system would see the impulse reach x_1 before it left x_0. The order of cause and effect would be reversed and by the principle of the independence of velocity the observer in the moving system has as much right to consider his observations real and his own system stationary as an observer in the system we designated arbitrarily as stationary. The invariability of the sequence of cause and effect forms a principle antecedent to all other laws of physical change. The process here presented should not be confused with certain common observations which present an apparent resemblance to a reversal of cause and effect. For instance, if a high-velocity projectile is fired above the head of an observer he may hear the sound of the projectile and later hear the report of the gun. But if he calculates the times of occurrence with consideration of the velocity of sound; he finds cause and effect occurred in the proper order. But in the process described before, the times presented as those of the moving observer are those he would calculate after allowing for the velocity of light.

This conclusion is inconsistent with Newton's form of the law of gravitation, which states that the force is inversely proportional to the square of the distance without regard to the velocities of the masses and therefore requires an infinite velocity of transmission.

There appears to be an impression among physicists that there is something about astronomical observations that requires that the velocity should be infinite, or at least much greater than that of light. This impression has had its origin in some early work by Laplace and some work by Lehmann-Filhés and by Hepperger. These investigators endeavored to calculate what velocity gravitational transmission would need to have to account for the variation from Newton's law exhibited by the motion of the planet Mercury. They concluded that the velocity would need to be exceedingly high. But in order to make their calculations it was necessary to make some assumption as to the manner of action of gravitation. Since Newton's law was not to be used, a new law must be assumed, and although they thought there

was logical basis for the laws they assumed, there is really enormous latitude of choice in this matter. It is quite as difficult to generalize from Newton's law, assumed to be applicable for a stationary system, to a general law applicable when velocities are involved, as though one familiar with Coulomb's law of the force between electric charges at rest should attempt to extend it to charges in motion, without a knowledge of the magnetic field.

All three of these investigators assumed that the force on the attracted body is not in the actual momentary direction of the attracting body, as required by Newton's law, but in the direction of the position the attracting body occupied when the gravitational wave left it. Laplace assumed that the magnitude of the force is the same as that indicated by Newton's law, the distance being taken as the actual momentary distance; while the other two employed the distance to the old position of the attracting body.

Laplace estimated that the velocity would need to be 100,000,000 times that of light to produce no more anomalous motion in Mercury than that observed. A velocity equal to that of light would have led to very great disturbances in the solar system, by his theory.

Hepperger, with the other theory of the manner of action, concluded that the velocity must be about 500 times as great as that of light.

On the other hand, in 1898 Gerber proposed still another theory of the manner of action, and from it calculated the necessary velocity to account for Mercury's perturbation, and found that it agreed well with the velocity of light.

We have now considered the evidence against Newton's theory, which may be summarized as follows:

1. It does not entirely account for the motion of Mercury and the motions of some other heavenly bodies.

2. The equation is not invariant to the Lorentz transformation.

3. It represents an infinite velocity of transmission, while the theory of relativity indicates that no velocity can be greater than that of light.

The last two of these are dependent upon the older theory of relativity, which depends in part upon postulates which Einstein has rejected in his recent theory of gravitation. This more recent theory is also inconsistent with Newton's theory, except under

certain conditions. We may now consider in what respects the law is supported by modern observations.

MASS FORCE AND ENERGY.

What has been presented so far is sufficient to show the importance of distinguishing between observations and theories that are valid only for velocities that are small relative to that of light, and those that are valid strictly for all velocities. The number of physical experiments that have given information valid for velocities approaching that of light is extremely small, and they have almost all been carried out in recent years. We must therefore be prepared, with open mind, to change if necessary some of our views relative to familiar principles when we attempt to apply them in so precise and rigorous a manner that these velocity effects must be taken into account. We must consider even the definitions of the most familiar physical quantities. The principles of Newton are valid for velocities that are negligibly small; as to their validity for velocities near that of light Newton had no evidence. He, of course, had no reason to suppose that the velocity of light has anything to do with them.

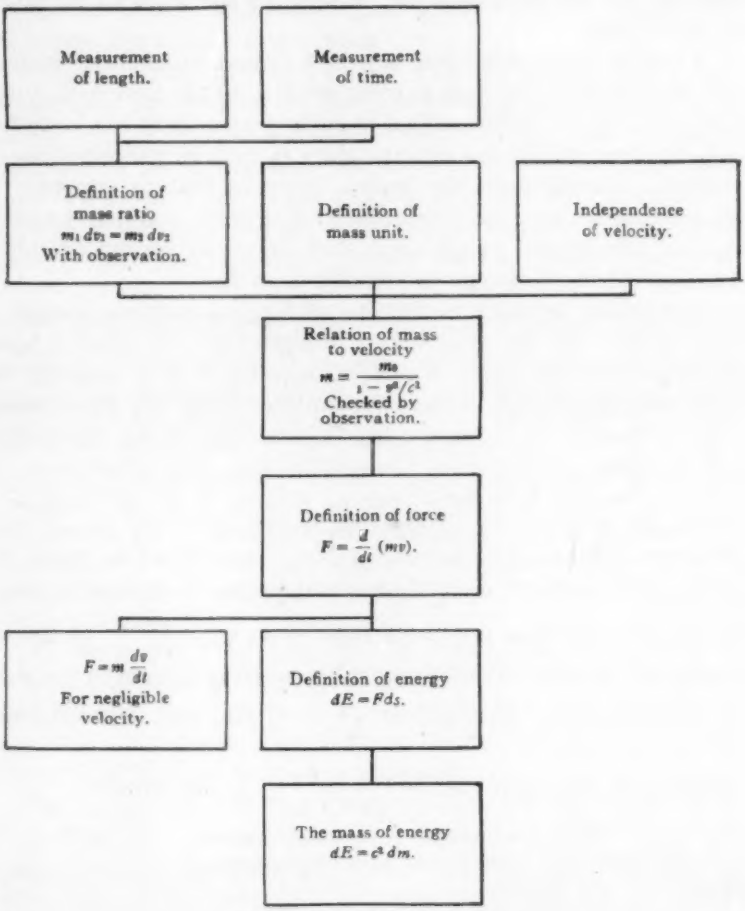
It appears therefore well worth while to consider our definitions of mass and force, for in spite of the fact that almost every high school student in physics is asked to define these quantities it is not easy to define them, even in terms of ordinary Newtonian mechanics. The definitions are to a certain extent arbitrary; one may define force in terms of mass or mass in terms of force, but one or the other must of course be defined independently. It is usual even among scientific writers to say, "We will accept the customary conception of mass and define force in terms of it," or, "We will employ the term 'force' with its usual meaning and define mass by the relation, force equals mass times acceleration."

I will not attempt an exhaustive treatment of these basic principles, but for the present purposes some statement of the meaning of the words we employ seems quite important, and I will again employ a diagram to present without too much detail a summarized statement of a single one of the possible sets of definitions and of certain important principles.

A definition of mass will first be given. If dv_1 and dv_2 represent the changes of velocity that two bodies undergo, each

as the result of the presence of the other body, the ratio of their masses m_1 and m_2 is defined by the equation $m_1 dv_1 = m_2 dv_2$. For completeness a unit of mass must be defined. This unit is familiar.

It is found by observation that the mass ratio so defined is


Measurement of length.
Measurement of time.
Definition of mass ratio $m_1 dv_1 = m_2 dv_2$ With observation.
Definition of mass unit.
Independence of velocity.
Relation of mass to velocity $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$ Checked by observation.
Definition of force $F = \frac{d}{dt}(mv)$.
$F = m\frac{dv}{dt}$ For negligible velocity.
Definition of energy $dE = Fds$.
The mass of energy $dE = c^2 dm$.

MASS FORCE AND ENERGY.

independent of the nature of the interaction between the two bodies, of the presence of neighboring bodies, and of the order in which the masses of the bodies are compared. I will not attempt to analyze these observations in detail. They form a part of the evidence of the conservation of mass.

It was formerly supposed that the mass ratio is also independent of the velocities of the bodies, as it is for small velocities, within the limits of observation. This is not true for large velocities, however. By means of the principle of independence of velocity we can determine the relation of the mass of an object to its velocity.

Consider two observers, one in a system considered stationary, the other in a system moving relative to the first with a uniform velocity v. Suppose that in each system there is a body and that the two bodies are exactly alike if each is examined by an observer moving with the body. Suppose that as the body in the moving system comes opposite to that in the stationary system the two are caused to act upon each other, by impact or otherwise, producing a change in velocity in each.

A's object appears to him to undergo a certain change of velocity du. By the principle of independence of velocity, since the bodies are the same, B's object appears to B to undergo the same velocity change in the opposite direction. By the Lorentz transformation we can find what this velocity in B's coördinates will be when expressed in A's coördinates. For illustration we will here assume that the change of velocity is at right angles to the direction of motion; a rigorous treatment of the general case gives the same result. In this case the measure of length in the direction of motion of the objects is the same in the two systems, but the units of time are in the ratio of $1 : \sqrt{1 - \frac{v^2}{c^2}}$. Hence the change of velocity of the object in the moving system in the units of the stationary observer is $\sqrt{1 - \frac{v^2}{c^2}}\, du$, and our definitive equation of mass gives $m_0 du = m \sqrt{1 - \frac{v^2}{c^2}}\, du$, where

m_0 = mass in stationary system
m = mass in moving system.

Hence

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

With the definition of mass that has been employed we find that the mass of a moving object, while dependent upon velocity, is independent of the relation of the direction of the velocity

to the direction of the change in velocity, as is shown if in our imaginary systems we consider the bodies moving in other directions than that we have chosen for simplicity. With another definition of mass, this is not the case, and we are forced to speak of transverse mass and longitudinal mass. Thus it appears that definitions have some importance.

This equation agrees very well with the actual observations of Bucherer and Hupka on the relation between the mass of an electron and its velocity. It agrees approximately with the earlier observations of Kaufmann, but it is now admitted that these observations must have been slightly in error. We have thus a striking agreement between observation and an entirely independent theoretical conclusion from the principle of independence of velocity.

We will now define the force exerted on a body A by a body B as $F = \frac{d}{dt}(mv)$, where $\frac{d}{dt}(mv)$ is the difference between the time rate of change of momentum of A in the presence of B and that in the absence of B. This is equivalent to $F = m\frac{dv}{dt} + v\frac{dm}{dt}$, and in the special case in which v is negligibly small it becomes $F = m\frac{dv}{dt}$. This equation is itself sometimes used as the general definition of force; but by the present definitions it is true only when velocities are negligibly relative to that of light, as in ordinary mechanics.

An element of kinetic energy may now be defined as the product of the total force exerted on a body and the element of distance through which the body moves in the direction of the force: $dE = Fds$. Since both the force and the motion pertain to a particular body, the kinetic energy does also.

The equations presented lead to the striking result of the proportionality of changes in kinetic energy and the accompanying changes in mass. This is obtained by elimination, as follows:

From the definition of energy,

$$dE = Fds.$$

From the definition of force,

$$dE = \frac{d}{dt}(mv)\,ds = \left[\frac{ds}{dt}\frac{d}{ds}(mv)\right]ds$$
$$= vd(mv)$$

From the equation,

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}, \qquad v = c\sqrt{1 - \frac{m_o^2}{m^2}};$$

$$dE = c\sqrt{1 - \frac{m_o^2}{m^2}}\, d\left[c\sqrt{m^2 - m_o^2}\right]$$

$$= c^2\, dm$$

This idea is not entirely new, for Maxwell's electromagnetic theory led him to the conclusion that light exerts an impulse upon a surface upon which it falls, and this was later confirmed by observation. An application of the principle of conservation of momentum led to the conclusion that light carries with it a moving mass; and the relation of this mass to the energy of the light is like that stated above.

From this point of view any change in the kinetic energy of a body, which includes the individual kinetic energies of its atoms and molecules, results in a change in its mass. An increase of one gram requires an energy increase of 9×10^{20} ergs.

This factor is so large that the amount of energy that can be added to a body by heating it, for example, would not produce a change of mass that could be detected. This energy of 9×10^{20} ergs equivalent to one gram, is equal to the heat of combustion of about 1600 tons of gasoline.

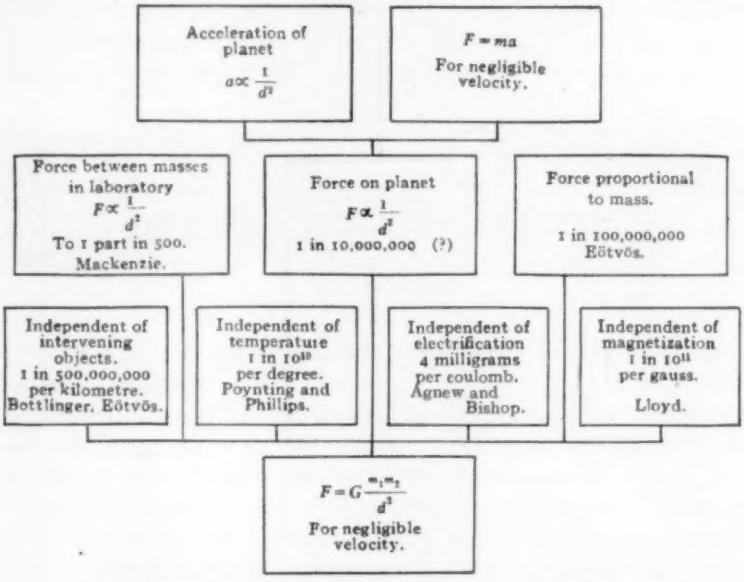
GRAVITATION WHEN VELOCITIES ARE NEGLIGIBLE.

We will now return to the subject of gravitation. We have found that the three pieces of evidence against Newton's law are all associated with the velocities of the bodies. We have no evidence against the law as applied to stationary bodies, and on the other hand much evidence collected since Newton's time has strengthened its position in this respect. A diagram of the evidence supporting the law as applied only to bodies with velocities small relative to that of light is therefore presented. Indications are given of the degree of accuracy with which it has been checked.

The astronomical evidence has already been presented briefly. It indicates, I believe, that the force is inversely proportional to the square of the distance within about one part in 10,000,000, although I am a little in doubt relative to this datum. Experi-

ments on masses in the laboratory by the torsion balance method show that the law is followed within one part in 500.

Eötvös has used some exceedingly sensitive torsion balances for the study of problems connected with gravitation. For the study of the relation of gravitative force to mass he used a balance consisting of a horizontal rod having at its ends two equal masses of different materials, and supported in the middle by a silica fibre. The two masses, like all masses on the earth, are acted upon by the force of gravity and also by the centrifugal



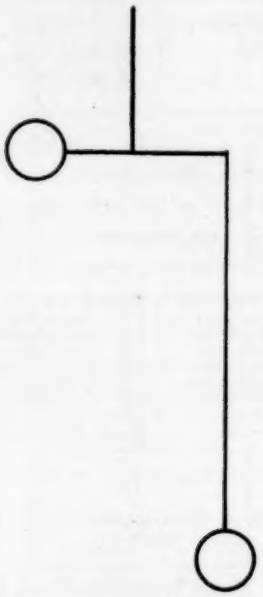
GRAVITATION WHEN VELOCITIES ARE NEGLIGIBLE.

force resulting from the earth's rotation. If the balance is set so that one mass is nearer the earth's equator than the other, a greater portion of the force on this mass will be centrifugal force than that on the other mass, which is nearer the earth's axis of rotation. If the ratio of gravitational force to mass is not the same for the two materials, the balance will have a tendency to turn, if set at a suitable angle. Whether a turning couple exists can be determined by rotating the top of the fibre through 180° and observing whether the suspension turns through exactly the same angle. The method is surprisingly sensitive, and he

showed that the attracting force is proportional to mass with an accuracy of one part in 20,000,000 and in some experiments of one part in 100,000,000.

In order to investigate the influence of intervening masses Eötvös employed a balance of the form shown in Fig. 1. The masses on this balance are attracted not only by the earth, but also by the sun. Suppose this apparatus is observed at sunset. All objects near the suspension being stationary, the only changes in

FIG. 1.



force to be considered are those resulting from changes in the relative position of the sun. Suppose the suspension placed with the arm perpendicular to the direction of the sun. In the following diagram the arm is seen endwise.

Before the sun begins to set there will be no obstruction between the masses and the sun, and the forces on them will be the same, and there will be no torque. But when the sun has set, a considerable thickness of the earth's crust will come between the balance and the sun, and just as the sun sets this will be considerably greater (by several kilometres) for the lower

mass than for the upper, and if the earth exerts any shielding action the lower mass will be attracted less strongly and the suspension will turn. No effect was observed, although a change of one part in 100,000,000 per kilometre of the earth intervening could have been detected.

Another test is afforded at the time of an eclipse of the moon, for at that time the earth is directly between the sun and the moon, and if there were any shie'ding action the motion of the moon would be disturbed. Bottlinger has ascribed some very small observed perturbations to this cause, but they correspond to a shielding action of only one part in 1,000,000,000 per kilometre of the earth; and it is likely that the observed effects were observational errors or caused by something else. At least we can

FIG. 2.

conclude that the shielding is not more than one part in 500,000,000 per kilometre.

Some observations on the effect of temperature, those of Shaw, are not in accord with the datum I have given in the chart but indicate a very large effect of temperature, when both of the attracting masses are objects in the laboratory, and the larger of the two is heated. However, they were obtained by a method having possible sources of error, and I do not think they should be considered conclusive.

The theory of relativity leads to the conclusion that increasing the kinetic energy of a body increases its mass according to the equation $dE=c^2dm$, and therefore that increasing the temperature of a body would increase its mass, but the effect would be too small to be observed. It would of course not be contrary to the stated law of gravitation, but would represent merely the transfer of a very small mass from one thing to another.

The experiments on the effect of electrification were made by weighing a condenser, charged and uncharged. Charging the condenser of course merely represented a transfer of electrons

from one side of the condenser to the other; so that the experiment merely indicates that this change produces no change in weight, not that an electron has no weight.

EINSTEIN'S THEORY OF GRAVITATION.

Einstein's theory of gravitation is based upon his equivalence hypothesis, according to which a uniform gravitational field of force is exactly equivalent to the effects of an acceleration of the system considered, when there is no gravitational field; so that no possible experiment can distinguish between them.

There are some common observations that illustrate this hypothesis and support it as far as they go. For instance, if we are riding in an elevator, as long as it is moving up or down with a uniform velocity we feel the familiar effects of gravitation and our feet press upon the floor with the same force. If the elevator is accelerated upward we seem to weigh more, the force between the floor and our feet is greater, and as far as we can observe, the effect is the same as though the force of gravity were greater; and the ordinary effects of gravity are the same, as far as we can observe, as those that might be produced by an acceleration. Einstein assumes that this relation, which we observe is at least approximately true, is strictly true no matter whether we observe ordinary mechanical effects or any phenomena whatever.

In order that it may be strictly true, it is necessary that the acceleration produced upon freely moving bodies by a gravitational field should be the same for all bodies; in other words, that weight should be proportional to mass. That this is true within very narrow limits has been shown by the work of Eötvös, already described. The equivalence hypothesis is thus dependent upon this observational principle.

This hypothesis is analogous to some principles we have already considered, such as the principle of independence of velocity. That deals with uniform velocity; the new hypothesis deals with uniform acceleration. However, there are differences which should be considered. The principle of independence of velocity states that an absolute velocity cannot be detected by any means. The equivalence hypothesis does not state that effects of uniform acceleration in the absence of gravity cannot be detected,

but only that the effects are not distinguishable from those of a uniform gravitational field. Further, the principle of independence of velocity is based upon observations involving not only mechanical effects, but also electrical and optical effects; and sufficiently accurate observations have been made to find the effects predicted from the old theory of a stationary ether if they existed; while Einstein's equivalence hypothesis had for its support only mechanical observations, for optical or electrical experiments of the necessary refinement had not at the time been made.

The applicability of the equivalence hypothesis is limited to *uniform* gravitational fields, and consequently to uniform acceleration. We cannot imagine the complicated accelerations, existing, for instance, throughout the cars of a moving train, as being equivalent to any changing gravitational field. Such a motion involves not only acceleration, that is, the second derivatives of position relative to time, but also the higher derivatives of position relative to time. Similarly the principle of independence of velocity applies only to uniform velocity, involving only the first derivative of position relative to time, not to accelerated velocity.

Making use of the equivalence hypothesis, Einstein employed it for a determination of the necessary form of the gravitation laws, by employing transformations of coördinates such as would correspond to the assumed equivalence of the two kinds of fields. His first step was to consider a transformation applied to the coördinates of the accelerated system such that referred to the new coördinates it would be a system at rest. In so doing he considered first that the space might or might not be Euclidian, and he also introduced the idea of a generalized theory of relativity. Before attempting to make clear his application of the equivalence hypothesis it is therefore desirable to give a little consideration to the principles of the transformation of coördinates.

CO-ORDINATE TRANSFORMATIONS AND GENERALIZED RELATIVITY.

We shall have occasion to consider changes not only of the coördinates of ordinary space but of a space that does not follow the geometry of Euclid, of a curved space, for Einstein has considered it necessary to introduce such a conception into his theory.

In so doing I do not wish to alarm you unduly as to the danger that space is really curved. The evidence does not yet force us to this conclusion, but if it is curved this is not so fantastic an idea as might at first appear. The idea has played a very important part in Einstein's theory and it is quite proper and indeed necessary that physicists should consider this possibility.

It is much easier to visualize the problem if we consider not a four-dimensional nor even a three-dimensional, but a two-dimensional curved space. Suppose that we have here a curved surface and imagine that some kind of beings inhabit this two-dimensional space, and that all the phenomena that they can observe are within that space, so that to them a three-dimensional space is a fantastic dream.

They can measure their space and calculate the curvature, in some cases at least, provided it is not too slight. Now how do they measure it? How do we measure our space? We take a metre stick and we observe that so far as we can see this stick has the same length no matter which way we turn it nor where we place it. Yet we really do not know that its length does not change; we know only that every measuring device and every object we can examine when their orientation and position are changed, change their lengths in the *same ratio*, so that two metre sticks that coincide when placed together in one position coincide when placed together in any other. This principle, which is an exemplification of the principles of independence of position and independence of orientation, is one of the most fundamental principles of physics, being antecedent to our conception of the measurement of length. We realize that our metre stick may not have the same length in all positions, but since we can not determine the change, we adopt the *convention* that it shall be considered constant.

That this convention, though a wise one, is not a necessary one I can illustrate by exhibiting a universe in which the situation is otherwise. Such a universe may be seen in a concave mirror. I have here a sheet of rectangular coördinate paper, and the lines appear to me equally spaced, and mutually parallel or at right angles. But here is a man in the mirror who has a sheet of paper on which the lines are curved, and they are not at right angles. Yet if he, like myself, takes a unit length and moves it along one of the lines he finds its length always corre-

sponds to the space between two divisions, because the unit changes as he moves it. And if I check the perpendicularity of these lines by holding a triangle first in one angle and then in its supplementary angle, he does the same, but his triangle changes when he turns it around, and he thinks his angles are right angles. But when he looks out of the mirror at us our space appears distorted, and he says, "That fellow out there is crooked and drunk, but my space is uniform and straight, and I use Euclid's geometry." In this point of view he is as justified as we are, and he exemplifies the wisdom of our convention that the length of our metre stick shall be considered as a constant.

With this convention the inhabitants of the two-dimensional space can make measurements in it and observe its curvature, just as surveys of the earth's surface can give evidence that the surface is approximately spherical, without the need of observing the celestial bodies, which are outside the surface. They will find it useful to employ a set of coördinates. If they think their surface is plane they will perhaps endeavor to employ Cartesian rectangular coördinates, but they may find that the lines in this system which in one region appear parallel will, if sufficiently extended, eventually meet, contrary to the axiom of Euclid. An axiom may be defined as an observation that has been so universally impressed upon us that we cannot imagine the possibility of the situation being otherwise. Euclid could not imagine that parallel lines in three-dimensional space should ever meet. Our imaginations have been further developed.

After setting up their coördinate or parametric lines, which may be arbitrarily any two infinite sets of lines such that one line of each set passes through each point of the surface, they will need to be able to estimate the length of a line in any arbitrary direction. If ds is the length of an element of such a line and du and dv are elements of lengths of the parametric lines, it can be shown by an elementary calculation that ds is given by an equation of the form

$$ds^2 = Edu^2 + 2F\,du\,dv + Gdv^2$$

in which the quantities E, F and G are in general different in different parts of the surface. From this they can determine something about the curvature of the surface. A surface has two principal radii of curvature ρ_1, ρ_2 in different directions.

From the above quantities they can determine what is called the Gaussian curvature, which is

$$\frac{1}{\rho_1\rho_2} = \frac{1}{2H}\left\{\frac{\partial}{\partial u}\left[\frac{F}{EH}\frac{\partial E}{\partial v} - \frac{1}{H}\frac{\partial G}{\partial u}\right] + \frac{\partial}{\partial v}\left[\frac{2}{H}\frac{\partial F}{\partial u} - \frac{1}{H}\frac{\partial E}{\partial v} - \frac{F}{EH}\frac{\partial E}{\partial u}\right]\right\},$$

in which

$$H = \sqrt{EG - F^2}.$$

For example, if we substitute $E = G = 1$, $F = O$, we find that the curvature is zero and the element of length is given by

$$ds^2 = du^2 + dv^2$$

which is the geometry of a plane with rectangular coördinates. The observers in the surface cannot determine ρ_1 and ρ_2 separately. If the Gaussian curvature is everywhere zero, the surface will appear to them to have all the properties of a plane, yet it may be what is known as a " developable surface," a surface which can be produced by bending a plane without stretching.

Now suppose that the inhabitants of the surface desire to use a different set of coördinates connected with the old ones by some relations:

$$u_1 = f_1(u, v)$$
$$v_1 = f_2(u, v)$$

If we apply this transformation to the ds^2 we obtain an expression of the same form, namely,

$$ds^2 = E_1\,du_1^2 + 2F_1\,du_1\,dv_1 + G_1\,dv_1^2,$$

where E_1, F_1 and G_1 are new quantities. The Gaussian curvature may now be obtained by the same equation as before, using E_1, F_1 and G_1 in place of E, F, G. Thus the curvature is invariant to any transformation of the coördinates, it is an intrinsic property of the surface, independent of the coördinates we use to express it.

In Einstein's problem we have to consider transformations involving not only position and time but also forces, and this seems to complicate the matter. Yet we measure forces only by the changes of position they produce. In fact, all *exact* observations of any kind are observations of the simultaneous coincidences of things in space. When we measure a mass, we do not put the mass in the same space as a standard mass and see whether they are alike, but observe under what conditions the pointer of a

balance coincides with the zero point on the scale. In electrical measurements we note the coincidence of the pointer of a galvanometer with a point on a scale or a spot of light from a galvanometer mirror with a scale.

It is true that we have physiological sensations of magnitude that are not obviously of this character. We gain some idea of the weight of a body by holding it in the hand, and we have sensations of temperature, color, etc. The visual estimation of length is associated with the coincidence of the image on the retina with particular points of the retina. We cannot analyze all these physiological processes, because we do not understand brain mechanism. Perhaps we may think of the coincidence of the excitation conveyed by a nerve, with a particular memory cell of the brain; but we need not worry about this, for physiological estimates are only qualitative, and physical measurements are never based upon them directly.

When a body moves in a straight line with uniform velocity we consider that there is no force acting upon it; this accords with our definition of force in terms of change of motion.

Einstein has proposed a new generalized principle of relativity. According to this principle all general physical laws must be expressible in such a form that they are invariant to any transformation of coördinates. It has been pointed out that the only things we ever really observe are coincidences, and coincidences do not depend upon coördinates.

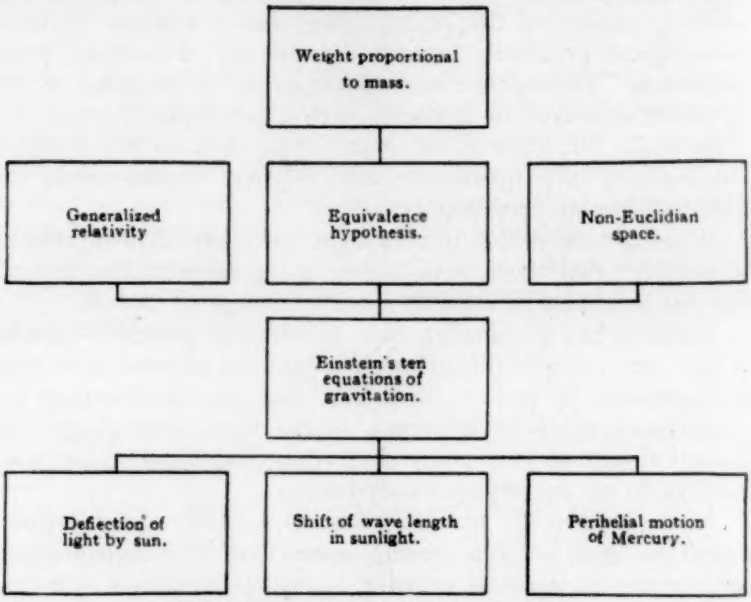
If we confine our attention first to ordinary space, without regard to time, we can readily admit that this must be true; and we are accustomed to using at will rectangular, spherical, cylindrical, ellipsoidal or other coördinate systems, as convenient. It is essential, however, that we should have to start with a principle which harmonizes with the true nature of our space, Euclidian or curved. Our expression for the length of an element of a straight line includes the specifications of the curvature, if it exists, and any transformations whatever of the coördinates of the space itself leave these specifications unchanged.

Minkowski showed on the basis of the Lorentz transformation the advantage of considering a four-dimensional space with coördinates x, y, z and ict. Minkowski's space is Euclidian; its curvature is zero. Einstein has also treated time as a fourth space coördinate, but he has discarded the older theory of rela-

tivity, because it was based upon the postulate of the constancy of the velocity of light, and his four-dimensional space is therefore not necessarily Euclidian, and leaves the curvature to be determined by the requirements of his equivalence hypothesis.

EINSTEIN'S THEORY OF GRAVITATION, continued.

We may now return to the problem of gravitation, and to keep our ideas clear I will repeat our problem. Our premise is that two systems, one accelerated and one having a uniform gravita-



EINSTEIN'S THEORY OF GRAVITATION.

tional field of suitable intensity, appear the same to observers in them. We wish to find the relations that must exist between the space-time coördinates of the two observers in order that this may be true.

Consider the accelerated system, which has no gravitational field. The acceleration must of course be produced by a force, and the force must be applied to the part of the system that forms the support, the part upon which it rests when subjected to a gravitational field without acceleration. It has been specified that the acceleration is uniform; there are no relative accelerations within the system. It is proposed now to apply a transformation

of coördinates so that relative to the new coördinates the system is at rest.

The transformed element of length is of the form:

$$\begin{aligned} ds^2 = {} & g_{11}\,dx_1^2 + g_{22}\,dx_2^2 + g_{33}\,dx_3^2 + g_{44}\,dx_4^2 \\ & + 2g_{12}\,dx_1\,dx_2 + 2g_{13}\,dx_1\,dx_3 + 2g_{14}\,dx_1\,dx_4 \\ & + 2g_{23}\,dx_2\,dx_3 + 2g_{24}\,dx_2\,dx_4 + 2g_{34}\,dx_3\,dx_4. \end{aligned}$$

The ten coefficients, the $g's$, are the only necessary characteristics of the transformation. By hypothesis the accelerated system was equivalent to a system with a uniform gravitational field. The $g's$ therefore represent a transformation from a gravitational field to the absence of one; they represent all the difference between such a field and the absence of one; they define the gravitational field. In the ordinary Newtonian theory the state of a gravitational field is determined by a single quantity, the potential; here we have ten quantities. The possible complexity of the theory is thus indicated.

We have now the problem of determining what the $g's$ represent and what are the relations among them; these relations must consist of or include the equations of gravitation. In this we are aided by the general principle of relativity, from which it follows that the relations must be invariant to all coördinate transformations; also by the fact that the equations must approach the old law of gravitation when the velocity approaches zero.

Just as the principle of independence of orientation leads to ordinary vector analysis, and that of invariance to the Lorentz transformation leads to a four-dimensional vector analysis, so the general theory of relativity requires invariance to a general transformation and requires the use of a general invariant theory, which has been employed in the form of the tensor analysis or absolute differential calculus of Ricci and Levi-Civita. Any adequate treatment of this in a short time is impossible.

The requirements of invariance to a general transformation, together with the requirement of giving the known equation for zero velocity, greatly limit the possible forms of the gravitation equations. Einstein has been led in this way to the selection of certain equations which appear necessarily true if the truth of the equivalence hypothesis is accepted.

Having found the $g's$, we can calculate the curvature of the four-dimensional space, by the application of a formula analogous

to that presented for two dimensions, and it is found that there is a curvature, which is zero in a uniform gravitational field, but is positive in space occupied by matter. What is meant by a positive curvature is illustrated in the case of two dimensions by the observation that when the curvature is positive the two principal radii of curvature have the same sign, that is, are on the same side of the surface, as in the case of a sphere. This has led Einstein to the idea that since the curvature of space is always in the same direction, the space may be analogous to a closed surface, such as a sphere; not a true sphere, since the curvature is not constant, but something like a wrinkled sphere. Of course a sphere is only a two-dimensional space existing in three dimensional or higher space. The space we are considering is the four-dimensional space, including time as one coördinate; and if we consider it curved we may imagine it existing in a space of higher dimensions. Our ordinary three-dimensional space would form a part of the four-dimensional space and would share the curvature.

The idea of the space being closed is merely one suggestion; it is not an essential part of the theory. It of course implies that space is finite and contains a finite amount of matter. Also, it leads to many bizarre conclusions. For instance, light radiating from a star in this space would pass completely around the space, if not stopped by intervening matter, and would then come together near its original position forming something approaching an image; but as millions of years would be required for the light to travel around, the original source of the light would usually have moved to a distant point.

It does not seem to me that proof that Einstein's equations are strictly correct would necessarily show that space is curved, for it may be that under certain conditions all our measuring devices in a particular region of space change their length in the same ratio, so that the change is not directly apparent to us, but may lead us to erroneous conclusions relative to the metrical properties of space.

Einstein's theory of gravitation is contrary to his older theory of relativity; not to the principle of independence of velocity, but to some of the conclusions which were drawn from this principle, for in deducing the Lorentz transformation he had assumed that the velocity of light is constant under all conditions, and that space is Euclidian.

The theory has led to three conclusions capable of comparison with observation.

It has accounted satisfactorily for the perihelial motion of Mercury. This has been considered a great triumph of the theory, yet it must be remembered that in 1898, before Einstein's first theory of relativity had been presented, Gerber proposed a comparatively simple law of gravitation which also accounted very well for the motion of Mercury; and it has since been shown that Gerber's theory, unlike Einstein's, accords with the older theory of relativity.

Einstein's theory has led to the conclusion that the velocity of light is variable, depending upon the gravitational potential, and that in consequence, light passing through a variable gravitational field would be deflected. He showed that the light of a star passing close to the sun would be deflected 1.74 seconds of arc. A deflection might be expected for other reasons than those of Einstein. The classical electromagnetic theory, as well as relativity, assign a certain mass to the energy of a ray of light. If this moving mass is subject to gravitation it is to be expected that it will be deflected by a gravitational field. We cannot calculate how much without a law of gravitation applicable to moving bodies. If merely as an example we apply Newton's law, although we believe it is not always applicable to moving bodies, we find the deflection would be just half that predicted by Einstein.

Einstein's theory has also led to the conclusion that an atom in a gravitational field of high potential would vibrate at a slower rate than one in a low potential; and therefore the spectral lines in light from the sun would be shifted a little toward the red, as compared with light produced in the laboratory.

The deflection of the light of a star by the sun can be observed by ordinary methods only during a solar eclipse. Observations were made of the eclipses of 1918 and 1919. Full scientific reports of any of these observations have not been published so far as I know, but some information about them has come from various sources. It was reported that no Einstein effect was observed in the eclipse of 1918. English astronomers appear to have found the effect in the observations of 1919 under more satisfactory conditions for observation, and the amount of deflection agreed with Einstein's prediction. The results of not all of the 1919 observations have been made public. If an effect is observed we have

also to consider the possibility of its being produced by a refraction by the sun's atmosphere.

The predicted displacement of lines in the sun's spectrum is about .008 Angstrom units, which is very small. In searching for this effect it is necessary to avoid confusion with pressure effects, and with the Doppler effect produced by the velocity of the luminous gases. A careful investigation has been made by St. John at the Mount Wilson observatory. To avoid the effects of pressure he has studied some cyanogen lines which are not affected by pressure. He avoided the Doppler effect produced by the rotation of the sun by comparing observations at different parts of the sun's disk. He found no displacement greater than .002 Å.

His observations have been confirmed by Evershed at the Kodaikanal Observatory in India. Evershed found in some cases displacements of about the predicted amount near the limb of the sun, but these were variable and appeared to be produced by motion of the luminous gas. This he confirmed very nicely by observing the spectrum of sunlight reflected by Venus from the farther side of the sun. He found there a shift in the opposite direction, indicating that at the time of his observations the gases were moving from the face of the sun around to the opposite side. The Einstein effect would always have the same sign.

The evidence seems at present rather favorable to Einstein's theory, though with this contradictory evidence we cannot yet consider the matter settled.*

If a real deflection of light has been observed it will be necessary to abandon some of the conclusions of the older relativity theory which were deduced from the assumption that the velocity of light is constant. If the deflection has been observed this alone hardly proves the correctness of Einstein's theory of gravitation, although it is strong evidence in its favor; as I have pointed out, a deflection might be expected upon other theories.

* Since the above was prepared for publication, it has been announced that the predicted displacements in the sun's spectrum have been found, and that the previous failures to find them have been explained. Also, more complete information is available relative to the eclipse observations, and it is generally conceded that they indicate a real deflection of light by the sun's gravitational field.

SIMPLE CHANGES WHICH EFFECT A MARKED IMPROVEMENT IN THE SCHREINER COLORIMETER.*

BY

C. W. DAVIS.

U. S. Bureau of Mines.

THOSE who have had occasion to use the Schreiner colorimeter will recall that the images of the comparison tubes are at some little distance apart so that the eye in determining an intensity match has to be moved from one image to the other across the interval between them. This not only makes an accurate comparison difficult, but also causes an eye-strain if many analyses are being run.

To eliminate these disagreeable features the following changes were made:

The open end of the chamber (through which the mirror is viewed) was closed by nailing a board across it in such a way that it was light-tight, but at the same time allowed the cover to slide. A hole one-fourth inch in diameter was bored in the centre of this closed end.

In changing the position of the comparison tubes so that the ten-inch inside tubes should be close together at the top and one inch apart at their lower ends, the supports of these inner tubes were taken off, bent at the proper angle, cut away on their inside edges and then replaced, close together, instead of at some little distance apart as they were formerly. The board above these supports was cut away, so that light could pass through the smaller tubes to the mirror without being obstructed. The supports of the outside comparison tubes were changed to conform to this arrangement by placing the outside supports farther apart and by replacing the common inner support by a wider one; all being so tapered that the outside tubes slipped over the smaller ones, the two sets being held parallel and concentric.

The reflector was removed and altered by cutting its mirror through the centre, parallel to its short edges, and by raising this cut intersection by placing under it and parallel to it a narrow strip

* Published by permission of the Director of the U. S. Bureau of Mines. Communicated by Dr. R. B. Moore.

of wood or cardboard, the thickness of which was determined by trial.

The mirrors were attached temporarily to their frame with thumb tacks, as indicated above, using a strip of wood about three-sixteenths of an inch thick (to raise their tangent edges), and the reflector was replaced in the apparatus and turned so that the reflections of the comparison tubes on the mirrors could be best seen through the hole in the end of the chamber. When the images of the bottoms of the small tubes were seen as two distinct circles, one on each mirror, the strip under the mirrors was too thin; and when only a small part or none of the images of the bottoms of the tubes were visible, the strip was found to be too thick. The height of the intersection of the mirrors was adjusted so that a circle was formed, the right half being the image of one-half the bottom of the right inside tube, and the left half being the image of half of the left inside tube. The mirrors were then firmly attached to the frame by means of small screws.

Whenever the reflection on each mirror did not appear as a semicircle, the mirror intersection was not directly over the point of tangency of the comparison tubes, and was moved from right to left and back again until the right position was found. When the semicircles did not unite to form a circle, but one appeared higher than the other, the lower end of the inner comparison tube whose image seemed too high was pushed back until the circle was made perfect.

All new parts and all new surfaces were painted dead black.

Our Schreiner colorimeter, changed as described, has been greatly improved, so that it gives more satisfactory service and no longer causes noticeable eye-strain.[1]

[1] This arrangement of the colorimeter was suggested by Dr. L. I. Shaw, of the Bureau of Mines, who saw its advantages through a few preliminary tests.

GOLDEN, COL.,
May, 1920.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

RECOMMENDED SPECIFICATIONS FOR BLACK PAINT, SEMI-PASTE AND READY-MIXED.[1]

[ABSTRACT.]

THIS specification for Black Paint, Semipaste and Ready-Mixed, is one of a series of specifications for paints and paint materials. It was prepared under the auspices of the Bureau of Standards with the coöperation of an interdepartmental committee organized for the purpose, and in coöperation with the Educational Bureau of the Paint Manufacturers' Association of the United States. Before final approval the specification was submitted to a large number of paint manufacturers whose suggestions were carefully considered.

The specification gives the required composition, methods of sampling, analytical methods for laboratory examination of both paste and ready-mixed paint, and describes acceptable methods of preparing the reagents to be used.

RECOMMENDED SPECIFICATION FOR OCHER, DRY AND PASTE.[2]

[ABSTRACT.]

THIS specification for Ocher, Dry and Paste, is one of a series of specifications for paints and paint materials. It was prepared under the auspices of the Bureau of Standards with the coöperation of an interdepartmental committee organized for the purpose, and in coöperation with the Educational Bureau of the Paint Manufacturers' Association of the United States. Before final approval, the specification was submitted to a large number of paint manufacturers whose suggestions were carefully considered.

The specification gives the required composition, methods of sampling, analytical methods for laboratory examination of both dry pigment and paste, and describes acceptable methods of preparing the reagents to be used.

* Communicated by the Director.

[1] Circular No. 94.

[2] Circular No. 91.

RECOMMENDED SPECIFICATION FOR IRON-OXIDE AND IRON-HYDROXIDE PAINTS.[3]

[ABSTRACT.]

THIS specification for Iron-oxide and Iron-hydroxide Paints is one of a series of specifications for paints and paint materials. It was prepared under the auspices of the Bureau of Standards with the coöperation of an interdepartmental committee organized for the purpose, and in coöperation with the Educational Bureau of the Paint Manufacturers' Association of the United States. Before final approval the specification was submitted to a large number of paint manufacturers whose suggestions were carefully considered.

The specification gives the required composition, methods of sampling, analytical methods for laboratory examination of both paste and ready-mixed paint, and describes acceptable methods of preparing the reagents to be used.

INKS—THEIR COMPOSITION, MANUFACTURE AND METHODS OF TESTING.[4]

[ABSTRACT.]

THIS is a circular of general information on the subject of inks. The composition and manufacture are discussed only briefly, but the methods of testing which are in use at the Bureau of Standards are given in sufficient detail to enable any chemist to use them.

After a brief introduction on the history of ink, there are discussions of writing and copying inks, ink tablets and powders, marking, canceling, stamping, duplicating, and sympathetic inks.

The methods used for the laboratory examination of all but the last of these kinds of ink are next taken up. Under the analysis of writing inks, for instance, are the following headings: Total solids, ash, iron, sulphuric anhydride, tannin, dye, chromium, penetration, fluidity, keeping quality, and resistance to light and reagents. For the other kinds of ink there is not such a variety of tests necessary.

The circular closes with a short bibliography.

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[3] Circular No. 93.
[4] Circular No. 95.

MEASUREMENT OF HYSTERESIS VALUES FROM HIGH MAGNETIZING FORCES.[5]

By W. L. Cheney.

[ABSTRACT.]

IN a former paper, the writer described a method (a modification of the "isthmus method") for measuring magnetic properties of ferro-magnetic materials. Very good results were obtained for normal induction but attempts to measure hysteresis values were not so successful, particularly in the case of the coercive force.

A study of the possible causes for the divergence of hysteresis data as compared with those obtained on standard apparatus has led the writer to believe that readings are affected by: (1) the residual magnetism in the core of the electromagnet after the primary circuit has been broken, (2) a change in the distribution of the flux about the specimen when the magnetizing force is changed from a high value to a low one, and (3) magnetic viscosity.

As a result of this study, a method for measuring the coercive force, which yields results comparing more favorably within the experimental error with data obtained on standard apparatus, has been developed. After repeated trials it was concluded that the method of measuring residual induction could not be improved upon.

The coercive forces and residual inductions from maximum magnetizing forces ranging from zero to 2500 gausses have been plotted against the latter as the independent variable. Both curves resemble in shape the intensity of magnetization curve.

MEASUREMENT OF PLASTICITY OF MORTARS AND PLASTERS.[6]

By Warren E. Emley.

[ABSTRACT.]

THE Bureau has been endeavoring for many years to measure the plasticity of wall plasters. Many methods for making this measurement have been carefully investigated and successively abandoned, a little more information on the subject obtained through each failure.

[5] Scientific Paper No. 383.

[6] Technologic Paper No. 169.

On the theory that plasticity depends upon the quantity of colloids in the material an unsuccessful attempt was made to measure this "colloidal content." The viscosity of a lime paste was found to give no indication of its plasticity. Measurement of the compressive strength of a green paste gives a figure for plasticity which meets the engineer's definition of the term, but does not meet that of the plasterer. The Atterbury method is not satisfactory because of the difficulty of determining the ends of the plastic range. Measurement of the rate of drying gives a good indication of the relative plasticities of materials when they are entirely different, but not when they are of similar nature. The Carson blotter test is excellent in the hands of an experienced operator, but the results cannot be recorded.

An instrument has been devised whereby the work done in spreading a plaster on a wall can be measured. A sample of the plaster is molded into cylindrical form on a porous plate. It is then pressed with a continuous screw motion against a stationary conical disk. The forces transmitted through the sample to this disk are measured. The porous base-plate acts as the undercoat on a wall to suck the water out of the sample; the disk acts as a trowel to spread the sample over the base-plate. The instrument enables one to measure the rate of drying of the plaster, the force required to spread it, and the thinness to which it can be spread. A proper correlation of these three factors leads to a definite expression of the degree of plasticity of the material.

LIME—ITS PROPERTIES AND USES.[1]

[ABSTRACT.]

THIS circular is intended to give general information as to what lime is, how it is made, and what it is used for.

Lime is made by heating limestone under certain conditions, whereby it is decomposed into an escaping gas, carbon dioxide, and a non-volatile residue, lime or quicklime. This lime, when treated with water, hydrates, or slakes. If water is used in great excess, a paste results; but if the amount is properly regulated, the hydration yields a dry powder, which is called hydrated lime.

Since natural limestones contain more or less magnesia, iron,

[1] Circular No. 30 (2d Edition).

silica, etc., the quality of the lime will depend to some extent upon the nature and amount of these foreign materials. It will also depend upon the way in which the stone is burned.

As a material for building construction, hydrated lime is better adapted than quicklime because it eliminates the labor usually required to do the slaking. It is used very largely as a brick mortar, as an ingredient in concrete, and in the scratch and brown coats of plaster. A particular grade of hydrated lime, noted for its plasticity, is sold as finishing lime and is used for the white coat of plaster.

Limestone, quicklime, and hydrated lime are used to a large extent as chemical reagents in the manufacture of other materials. In some of these industries the quality of the lime is of minor importance. In others, the use of only one of the three forms of lime is satisfactory, and the quantity and kind of impurity which the lime may contain is definitely specified.

Eighteen of the most important chemical industries that use lime are enumerated. Brief descriptions of these industries are given, showing why and how they use lime and the quality of lime which they require.

A list of the tests of lime which are usually made includes chemical analysis, rate of hydration, plasticity, sand-carrying capacity, time of set, compressive strength, proportion of waste, and fineness.

THE VARIATION OF RESIDUAL INDUCTION AND COERCIVE FORCE WITH MAGNETIZING FORCE.[8]

By R. L. Sanford and W. L. Cheney.

[ABSTRACT.]

THIS paper is a report of an investigation to ascertain whether or not analytical expressions similar to the reluctivity relationship of Kennelly correctly represent the variation of residual induction and coercive force with the maximum magnetizing force. Hysteresis measurements were made on a number of samples covering a wide range of materials using magnetizing forces up to 2500 gausses. The relationships $H_m/B_r = a_1 + b_1 H_m$ and $H_m/H_c = a_2 + b_2 H_m$ were found to hold within the limits of the probable experimental error.

[8] Scientific Paper No. 384.

AN ELECTRON TUBE TRANSMITTER OF COMPLETELY MODULATED WAVES.[9]

By Lewis M. Hull.

[ABSTRACT.]

IN order to utilize a radio frequency wave train of given power most effectively in a non-oscillating receiving system, it must be completely modulated at some suitable audio frequency. There are two possible methods of accomplishing this when an electron tube generator is used: The use of a direct voltage supply with a mechanical chopper or interrupter, and the use of audio frequency alternating e.m.f. The first method may be inconvenient if a large supply voltage is used, whereas the latter scheme may be so employed as to give excellent overall transmitter efficiency without the use of the high direct voltage. An alternator may be used to supply the power, with suitable transformers for both the filament and plate circuits.

A compact transmitting set of this type has been designed and built at the Bureau of Standards. A description of this set, with photographs and diagrams, is given. It has been used in fog-signalling tests, supplying 200 watts of power to an antenna having a resistance of 8 to 15 ohms, at wave-lengths of 500 to 1000 metres. Overall efficiency, from terminals of the 500-cycle alternator to the antenna, as high as 35 per cent. is obtained with this set. Transmission and reception tests have shown that the waves from this transmitter cannot be received, using a crystal detector, over as great distances as waves from a spark set of the same power, but for heterodyne reception it is practically the equivalent of a continuous wave transmitter of equal power output, and can be received over a somewhat smaller range with any non-oscillating detector.

RECOMMENDED SPECIFICATIONS FOR QUICKLIME AND HYDRATED LIME FOR USE IN THE COOKING OF RAGS FOR THE MANUFACTURE OF PAPER.[10]

[ABSTRACT.]

THIS is the first of a series of specifications for the lime used in various chemical industries. The new specification is based

[9] Scientific Paper No. 381.

[10] Circular No. 96.

on a draft originally prepared at the Bureau of Standards. To assist in perfecting the specification, the Bureau of Standards called an interdepartmental conference of representatives of several bureaus most concerned. As revised, the specification has the unanimous approval of those concerned, including the National Lime Association and the Technical Association of the Pulp and Paper Industry. In addition to giving the percentage maxima or minima of the significant constitutents, detailed regulations are given for the packing and marking, and careful directions for the analytical methods used.

THE SPECTRO-PHOTOELECTRIC SENSITIVITY OF THALOFIDE.[11]

By W. W. Coblentz.

[ABSTRACT.]

EXPERIMENTAL data are given on the spectro-photoelectric sensitivity of Case's preparation of thallium-oxy-sulfide, thalofide, when exposed to thermal radiation of wave-lengths extending from 0.58μ to 3μ.

This substance has a wide unsymmetrical band of photosensitivity, which terminates abruptly at 1.2μ. The effect of temperature was investigated. The application of this substance to stellar radiometry is discussed.

A NEW MICROPHOTOMETER FOR PHOTOGRAPHIC DENSITIES.[12]

By W. J. Meggers and P. D. Foote.

[ABSTRACT.]

THE new microphotometer for measuring photographic densities is essentially the micropyrometer described in the Bulletin of the Bureau of Standards (Vol. 9, p. 475; 1913) except that a microscope of higher power is used. The photographic plate is mounted just below the objective of the microscope on a horizontal bed movable with a graduated screw and is illuminated beneath by an intense beam of light from a tungsten ribbon lamp.

[11] Scientific Paper No. 380.

[12] Scientific Paper No. 385.

Light transmitted by a small portion of the photographic plate, the image of which is adjacent to that of the tip of the pyrometer lamp, is matched with equal filament brightness by adjusting the current through the lamp. The ammeter readings are readily translated into measurements of photographic density. If the tip of the pyrometer lamp filament be regarded as a filar in the eyepiece, the relative positions or wave-lengths of spectral lines on a plate are measured at the same time that their photographic densities are measured.

An example of the use of this microphotometer for measuring wave-lengths and densities of spectral lines is given and it appears that the visually estimated intensities of such lines is a geometric series in accordance with Fechner's law.

Illustrations of this microphotometer's application to the measurement of energy distribution in a broad spectral line and to the measurement of spectral sensitivity of a photographic plate, are given.

Measurements of photographic density when the plate is illuminated by parallel light are found to be much larger than when the illumination is diffuse. This experience calls attention to the importance of specifying the character of the illumination when measurements are made on light transmission of diffusing media.

NOTES ON THE TESTING OF MAGNETIC COMPASSES.[13]

By R. L. Sanford.

[ABSTRACT.]

THE work of the Bureau of Standards on magnetic compasses was undertaken in response to requests for information and coöperation from the War Department and the United States Shipping Board. It consisted of studies of the behavior of various types of compasses, the construction of special apparatus for testing purposes, and special investigations. The information thus obtained was utilized in the preparation of specifications for various types of compasses and also in the preparation of specifications for testing.

In the course of this investigation, certain facts concerning the general characteristics of campasses were brought out which

[13] Scientific Paper No. 382.

were considered to be of interest to users of magnetic compasses. This paper gives a brief discussion of the principal performance characteristics of magnetic compasses together with a description of some of the apparatus which is used at the Bureau for testing.

PERMEABILITY OF RUBBER TO GASES.[14]

By J. D. Edwards and S. F. Pickering.

[ABSTRACT.]

CERTAIN of the factors which determine the permeability of rubber to gases have been investigated and the relative rates of penetration of a number of gases determined. The major findings may be summarized as follows:

1. The permeability of rubber compounds varies with the composition as would be expected. The aging of rubber films is accompanied by a decrease in permeability. A similar decrease may be affected by over-vulcanization. The rubber which shows a very low permeability for these reasons is usually very much deteriorated and frequently brittle so that it is a disadvantage from the standpoint of gas lighters.

2. The permeability to any gas is found to be directly proportional to its partial pressure provided the total pressure is constant. The variation of permeability with total pressure depends on the thickness of the rubber, the way in which it is supported, etc.

3. The permeability to hydrogen is inversely proportional to the thickness of the rubber. No other gas was tested in this respect.

4. The specific permeability to hydrogen at 25° C. of vulcanized rubber similar to the grade known as dental dam is about 20×10^{-6} c.c. per minute. This value varies somewhat with the age and chemical characteristics of the rubber.

5. The temperature coefficient of permeability is quite high. For example, in the tests at 100° C., the permeability to carbon dioxide or helium was about 17 times the rate at 0° C.; the permeability to hydrogen was about 22 times as great at 100° as at 0° C.

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[14] Scientific Paper No. 387.

6. The relative permeability of rubber to some common gases is shown in the following summary:

Gas	Relative Permeability Hydrogen = 1
Nitrogen	0.16
Air	0.22
Argon	0.26
Oxygen	0.45
Helium	0.65
Hydrogen	1.00
Carbon dioxide	2.9
Ammonia	8.0
Methyl chloride	18.5
Ethyl chloride	200.0

7. The permeability of rubber to water vapor is high—approximately 50 times the permeability to hydrogen. The value not having been determined with any precision is not included in the table above.

ATOMIC THEORY AND LOW VOLTAGE ARCS IN CÆSIUM VAPOR.[15]

By Paul D. Foote and W. F. Meggers.

[ABSTRACT.]

Theoretical.—On the basis of several possible theories of atomic structure it is shown that the *normal* operation of an arc below ionization might result in the excitation of a single line spectrum, a single series spectrum, or a group spectrum consisting of certain lines of different series. This latter conclusion follows from an extension of Bohr's theory. Thus if inelastic electronic-atomic impact occurred resulting in the ejection of an electron to the p th ring, the electron in returning to the n th ring or equilibrium may produce any combination of lines represented by inter orbit transitions within this range, the single line spectrum being a special case where $p = n + 1$.

A simple explanation is offered of fluorescence phenomena in vapors of the alkali metals.

A mechanism of absorption of radiation is described and the theory proposed by K. Compton that the ionization of an atom below the ionization potential may be explained by absorption

[15] Scientific Paper No. 386.

of radiation arising in other atoms from electronic-atomic impact of insufficient energy to ionize is further discussed. This hypothesis suggests that vapors of the alkali metals may be so stimulated that the 1st and 2nd subordinate series lines, instead of the principal series, tend to become absorption lines.

Experimental.—The cæsium spectrum was photographed for various accelerating voltages from λ 3878 to λ 9208 by use of dicyanin stained plates. The sensitivity of the plates was investigated by density measurements of the spectrum of a black body having a known energy distribution. The general characteristics of the plates were determined and all lines of the cæsium spectrum were reduced to an absolute scale of intensity by means of density measurements made with a microphotometer and consideration of the plate sensitivity. No evidence of group or single series spectra could be obtained. Thus the ratio of intensities of the first and second lines of the principal series, both of which should appear in a single series spectrum or above 2.7 volts in a group spectrum, rapidly approaches infinity as the accelerating potential in the arc is decreased. This ratio is 350 in a 7 volt arc, 2100 at 4 volts, 10,500 at 3.4 volts and as near infinity as can be measured at 2.8 volts. Similarly the intensity ratio of either $1.5\,s - 2\,p_1$ or $1.5\,s - 2p_2$ to any other line approaches infinity at low voltage proving for the first time the existence of a single line spectrum rather than a single series or group spectrum; in the case of cæsium the doublet λ 8521 and λ 8943.

The doublet $1.5\,s - 2p$ is alone produced under excitation of 1.5 to 3.9 volts accelerating field. The intensity of both of these lines gradually increases approximately proportional to the total number of electrons reaching the anode until the ionization potential is reached. At this point a pronounced decrease in intensity of these two lines occurs amounting to the factor one-third.

This decrease takes place at the voltage at which the complete line spectrum is produced and is readily explainable on the basis of Bohr's theory; in fact it affords a strong argument for this theory. Thus the lines $1.5\,s - 2p_1$ are the result of inelastic collision with electrons having velocities between 1.45 and 3.9 volts but as the latter voltage is exceeded electrons, which at a

slightly lower velocity would have given rise to $1.5s—2p_1$, now produce the complete series spectrum; and any line of the series $1.5s—mp$ where $m>2$ is necessarily excited at the sacrifice of $1.5\,s-2p_1$.

Above a certain voltage, the intensity of any line per unit number of electrons reaching the anode attains a saturation value, in agreement with the quantum hypothesis which requires that the number of quanta radiated be proportional to the number of collisions, and hence (approximately) to the number of electrons present.

Curves are given showing the relative intensities of the prominent cæsium lines at various voltages. The ratio of intensities of the components of the first doublet of the principal series $\lambda\,8521/\lambda\,8943$ is constant and equal to 1.5 from 1.5 volts to 120 volts.

The cæsium arc of the type employed does not rectify alternating current of 120 volts.

Sodium and potassium occurring as an impurity of the cæsium similarly exhibited the single line or doublet spectrum $1.5\,s-2\,p_1$ below their respective ionization potentials.

Only two types of inelastic impact between electrons and atoms of the alkali metal vapors occur, at potentials known as the resonance and ionization potentials and given by the quantum relation $\lambda\nu$ where $eV=\nu=1.5\,s-2p_1$ and $\nu=1.5\,s$.

Malaria Control From the Engineering Point of View.—Since malaria is spread by the *Anopheles* mosquito, the disease is best controlled by eradication of the mosquito, especially by elimination of its breeding places. According to W. G. STROMQUIST of the U. S. Public Health Service (*American Journal of Public Health*, 1920, x, 497–501) this end may be attained by drainage of the infected swamps, by oiling, or by means of fish. In drainage by ditches, a small V-shaped ditch should be cut in the bottom of the larger ditch. In oiling, the water surface frequently must be cleared. As to fish, the top water minnow, *Gambusia affinis*, is a deadly enemy of the mosquito, since it has a voracious appetite for the larvæ of the latter; this minnow must be protected against larger fish; and vegetation and other protection of the larvæ must be removed.

J. S. H.

NOTES FROM NELA RESEARCH LABORATORY.*

PURITY OF PALLADIUM USED IN GOLD-POINT PALLADIUM-POINT BRIGHTNESS RATIO.

By Edward P. Hyde and W. E. Forsythe.

In the *Astrophysical Journal* for May, 1920, data were published on the gold-point palladium-point brightness ratio. At that time no analysis had been made of the palladium used. Inasmuch as the value for the melting point was somewhat higher than that obtained by Day and Sosman in their work with the nitrogen thermometer, a question was raised concerning the purity of palladium. It has since been possible to test this point, using two separate methods. Through the courtesy of Doctor Sosman, of the Geophysical Laboratory, a small sample of the palladium used by Day and Sosman was obtained, making possible a comparison of its melting point with that used in this Laboratory.

Both samples were mounted between platinum wires, in the manner described in the original paper, and alternate melts were made in a platinum-wound black-body furnace. At the time of melt the e.m.f. of the thermocouple was read and recorded. The furnace was then held at this temperature and readings made with the optical pyrometer. At least six readings were made with the optical pyrometer for each melt. The average results of twenty-six melts, twelve on one sample and fourteen on the other, showed a difference between the melting-point temperatures of the two samples of very close to one degree, that furnished by the Geophysical Laboratory being higher. The thermocouple and pyrometer readings agreed to within less than this difference.

Small amounts of both samples were then sent to the Bureau of Standards for a spectroscopic analysis. Both samples were found to be nearly spectroscopically pure and showed only minute traces of silicon and lead. The sample from Nela Research Laboratory contained more lead but less silicon than that from the Geophysical Laboratory. They further reported that they

* Communicated by the Director.

have not yet carried their investigations on the platinum family of metals far enough to give accurate quantitative results from spectral examination, but from experience with other alloys estimate that minute traces represent 0.001 to 0.01 per cent. in the cases of silicon, lead and gold.

The above tests show that there is but very little difference between the melting points of the palladium used by Day and Sosman and that previously used in this Laboratory, the indications being that the Geophysical Laboratory palladium has a slightly higher melting point.

NELA RESEARCH LABORATORY,
CLEVELAND, OHIO,
July, 1920.

Mica. (*U. S. Geological Survey Press Bulletin No. 448*, June, 1920.)—Persons who are interested in deposits of mica should note the statement of the United States Geological Survey that only a large deposit of mica favorably located with regard to transportation and a grinding mill can be profitably worked solely as a source of scrap mica for grinding. Most mica mines must also yield good sheet mica to make the mining profitable. Mica to be of value as sheet must yield rectangles at least one and a half by two inches which must split easily and evenly, be free from cracks, markings, and fracture lines, and be reasonably free from specks or foreign mineral matter. The size stated is the smallest rectangular size which is salable as uncut sheet and the rough-trimmed mica sheet must be nearly twice as large to yield the rectangle stated. In order to be profitable most deposits must also contain some mica larger than one and a half by two inches.

If mica did not usually contain much foreign matter and did not have so many fissures and imperfections—cracks, markings and holes—there would be no difficulty in obtaining all the mica needed. But, in proportion to the mica mined there is only a very small percentage of sheet mica which when finally prepared is of the proper quality to be used in the industries.

Good sheet mica should be so flexible that a sheet a thousandth of an inch thick can readily be bent into a cylinder one-quarter of an inch in diameter without showing any cracking.

There is also a great variation in the hardness of mica, the Geological Survey recognizing seven different degrees of hardness. Mica is often erroneously called isinglass. This latter substance is a gelatin made of the air bladders of certain fish. The substance is soluble in water and burns readily, whereas mica is neither soluble nor combustible.

The production of the various kinds of mica in the United States ranges from 3000 to 5000 tons a year.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

A METHOD AND INSTRUMENT FOR THE MEASUREMENT OF THE VISIBILITY OF OBJECTS.[1]

By L. A. Jones.

THIS paper is a report of the research work done during the war in an effort to determine the best method of painting a vessel in order to obtain low visibility. The theoretical aspect of the subject is considered at some length, and a description of the instrument built for the measurement of visibility is given. The factor used to express the weather conditions from the visibility standpoint (that is, the optical factors of the weather condition) is defined and is termed the " weather co-efficient." Curves showing the theoretical relation between visibility and the weather co-efficient and between visibility and the reflection factor of the object considered are given. Finally, curves plotted from actual measurements are compared with the theoretical curves, and fairly good agreement is shown.

THE IMPORTANCE OF THE NODAL POINTS IN LENS TESTING.[2]

By G. W. Moffitt.

THIS paper deals with the interpretation of the lens bench measurements when no collimator is used and when the object distance is limited.

In such cases the lens does not pivot on the second nodal point when lateral shift of the image is eliminated for small rotations of the nodal slide, but on a point which divides the separation of the nodal points into parts proportional to the magnification.

The complete formula for calculating the true focal length is

* Communicated by the Director.

[1] Communication No. 79 from the Research Laboratory of the Eastman Kodak Company, and published in *Phil. Mag.*, Jan., 1920, p. 96.

[2] Communication No. 89 from the Research Laboratory of the Eastman Kodak Company, published in *J. Opt. Soc. Amer.*, 1920.

derived, and the conditions under which the ordinary approximate reduction is sufficiently accurate are discussed. An important conclusion is that the true equivalent focal length of any lens cannot be determined with certainty unless the apparent separation of the nodal points for the object distance actually used be determined.

For the correct reduction of field readings under the conditions of the test, additional formulæ are derived. Strictly speaking, one cannot deduce from such a set of readings what the field aberrations would be for a plane object at any distance from the lens. With respect to photographic distortion, there is no reduction that rigidly satisfies the problem in general, but an approximation sufficiently good for all practical purposes is obtainable in nearly all cases.

These refinements need not be taken into account in many cases, but it is always necessary to determine actually whether or not they may be ignored.

A METHOD FOR DETERMINING THE PHOTOGRAPHIC ABSORPTION OF LENSES.[3]

By G. W. Moffitt.

[ABSTRACT.]

THE axial photographic transmission co-efficient of a lens system for a given set of conditions will here be defined as the ratio of the light flux of photographic quality in the image of a small object on the axis of the system to the light flux of photographic quality that would reach the image were there no losses of any kind in transmission through the system other conditions remaining the same.

The method employed in determining this co-efficient involves the photographing of the lens image of a controlled circular source of approximate daylight quality and radiating according to the Lambert cosine law. Immediately after the completion of

[3] Communication No. 87 from the Research Laboratory of the Eastman Kodak Company. Read at the St. Louis Meeting of the American Physical Society, December, 1919, and published in *J. Opt. Soc.*, May, 1920, p. 83.

the lens exposure strips of the plate on both sides and adjacent to the lens image are impressed in a series of steps by direct action of the same controlled source in such a manner that the exposure in each step is continuous from beginning to end. From the developed plate the ratio of the times of exposure for equal densities in strips and image may be found. This ratio, together with the dimensions of the apparatus and the lens, gives sufficient data for the determination of the transmission co-efficient of the lens for light of photographic quality. If dependable results are to be obtained, care must be exercised in screening the plate from the action of stray light, from nearby objects during the sensitometer exposure and from barrel reflections during the lens exposure. These later may easily be eliminated by using a stop considerably less than the maximum, thereby eliminating the reflected light from cell rings and lens edges.

The entire light flux directed towards the entrance pupil of a lens system from a small element of source dS_o on, and perpendicular to, the axis of the system and radiating according to the Lambert cosine law is

$$L = \pi I_o dS_o \sin^2 U$$

in which I_o is a constant characteristic of the source and U is the angle subtended at the source by the radius of the entrance pupil. Were there no losses this flux would ultimately be uniformly distributed in the image whose size is controlled by the magnification. The flux density in the image (angle of incidence on plate disregarded) would therefore be

$$I_i = \frac{\pi I_o \sin^2 U}{Y^2}$$

in which Y is the lateral magnification assumed positive for real images.

Now if a photographic plate be directly exposed to the action of radiation from a plane circular source parallel to the plate and radiating according to the Lambert cosine law the flux density at the plate will be

$$I_s = \frac{\pi I_o R^2}{R^2 + l^2}$$

in which I_o is the constant characteristic of the source and R its radius, and l is the perpendicular distance from the source to the plate.

From these fundamental equations the expression for the transmission co-efficient may easily be found to be

$$T = \frac{t_s}{t_i} \cdot \frac{R^2 Y^2}{(R^2 + l^2)^2 \sin^2 U} = \frac{t_s}{t_i} \cdot \frac{R^2}{R^2 + l^2} \left[Y^2 + \frac{[Y(f+d)+f]^2}{h^2} \right]$$

in which t_s/t_i is the ratio of exposure times for equal densities in strips and image, d is the distance from the first principal point of the lens system to the entrance pupil considered positive when the entrance pupil is farther away from the source than is the first principal point, and h is the radius of the pupil. The equivalent focal length of the system is represented by f and the other symbols have the meanings already stated. When the object distance is large Y is small and may become negligible in comparison with f, in which case the equation reduces to the following simple form

$$T = \frac{t_s}{t_i} \cdot \frac{4R^2 S^2}{R^2 + l^2}$$

in which S is the F-number of the lens.

Because of inherent irregularities in the photographic plate, quite a number of exposures must be made in order to arrive at a good average value of the transmission co-efficient. The preliminary results obtained have been found to be in good general agreement with those found by visual methods [4] as well as with values deduced from the theory of reflection and absorption.

Antagonistic Properties of Different Regions of the Spectrum. GUSTAVE LE BON. (*Comptes Rendus*, June 14, 1920.)—It has long been known that the ultra-red rays destroy phosphorescence, while rays belonging to the visible spectrum produce it. Let a zinc sulphide screen receive sunlight which has traversed a vessel containing sulphate of quinine. The screen does not phosphoresce. Now let a vessel with ammoniacal sulphate of copper be placed in front of the quinine solution. The screen no longer remains dark but glows. The following is the explanation. The quinine solution transmits all the rays which destroy phosphorescence and only a part of those rays which produce it. The copper sulphate solution absorbs the larger part of the destructive wavelengths, red and infra-red, while it transmits, as its color shows, the blue end of the spectrum which favors phosphorescence. This group of wave-length is not absorbed by the second solution, so it reaches the screen and produces its effect. G. F. S.

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[4] P. G. Nutting, *Astrophys. Jour.*, **40**, pp. 33–42, 1914; R. W. Cheshire, *Proc. Opt. Con.*, pp. 34–40, 1912.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE COMPOSITION OF OIL OF CHENOPODIUM FROM VARIOUS SOURCES.[1]

By E. K. Nelson.

[ABSTRACT.]

AN examination was made of the composition of oils of chenopodium derived from the plants cultivated in the producing district of Maryland, from the wild plants growing in Florida and the Eastern States, from plants grown in Java, and also of oils produced in the United States and used in Brazil for the treatment of hookworm disease.

The oils from cultivated domestic plants were found to comply with the requirements of the United States Pharmacopœia and to contain from 60 to 77 per cent. ascaridole. Oil distilled in Java from plants grown in that country was found to be similar to the oils of American origin. The oils distilled from wild plants proved to be similar in composition to the oils from cultivated plants, except that they were very deficient in ascaridole.

Emphasis is placed upon the necessity of carefully observing certain precautions in the distillation of chenopodium oil from the plant, to avoid the decomposition of the ascaridole by prolonged contact with steam or boiling water.

The terpenes of chenopodium oil were found to consist of a mixture of *p*-cymene, *l*-limonene, and probably α-terpinene.

INSECT POWDER.[2]

By C. C. McDonnell, R. C. Roark, and G. L. Keenan.

[ABSTRACT.]

THE fact that flowers of certain species of Pyrethrum possess the property of killing various insects was known to the people of eastern Europe more than a century ago. Since that time this knowledge has gradually spread, until insect powder is now a

* Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Chem. Soc.*, **42** (1920), 1204.

[2] U. S. Dept. Agr. Bull. 824, issued June 3, 1920.

common household convenience. This powder owes its insecticidal activity to a mixture of acids and esters which first benumb and subsequently kill the insects brought into contact with it. While it is generally considered to be harmless to the higher animals, a number of cases where it has produced symptoms of a more or less serious nature are recorded.

In the enforcement of the Insecticide Act, insect powder has been found adulterated in a variety of ways.

Physiological, chemical, and microscopical methods which can be used satisfactorily in detecting adulteration with powdered stems, the most common form of sophistication, have not as yet been perfected to such a degree as to make an accurate quantitative determination possible. However, from the data obtained in the examination of hundreds of samples of genuine insect powder, of the materials used for its sophistication, and of commercial samples, the results of which are reported in this bulletin, a formula has been developed by which it is possible to determine in an insect powder the approximate amount of added Pyrethrum stems present.

SUMMARY OF BUREAU OF CHEMISTRY INVESTIGATIONS OF POISONING DUE TO RIPE OLIVES.[3]

By G. G. DeBord, R. B. Edmondson, and Charles Thom.

THE Bureau of Chemistry has examined 2161 commercial containers of ripe olives. Of these, 560 were glass and 1601 were tin. Cultural examination of 618 containers checked very closely with odor and appearance as determining the proper condition of the product.

Bacillus botulinus was found in material directly concerned in or taken from the pack that caused six groups of poisoning cases during the year. The organism belonged to Type A of Dickson and Burke. The toxic material examined was consistently sufficiently spoiled to be recognized as offensive by odor, especially at the time of opening the can. Emphasis is placed upon the responsibility of the person who opens a sealed container of food for determining its soundness before tasting it or serving it to others. Spoilage in any form condemns the product to destruction.

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[3] Published in *J. Am. Med. Assoc.*, **74** (1920), 1220.

With reference to olives, the serious contaminations found were attributed to the practice of pre-fermenting the product by shipping and holding the olives in weak brine. The pre-fermentations encountered in different lots varied from a purely acid type to one pronouncedly putrefactive. All of these products were ultimately processed, and carried their contamination over into the canned product, making sterilization difficult.

SOME PROTEINS FROM THE GEORGIA VELVET BEAN, STIZOLOBIUM DEERINGIANUM.[4]

By Carl O. Johns and Henry C. Waterman.

[ABSTRACT.]

THE Georgia velvet bean contains 23.6 per cent. of protein ($N \times 6.25$). Salt solutions of optimum concentrations (3 per cent.) extract about 15 per cent. of protein. From such solutions two globulins, designated the α- and β-globulins, and an albumin may be separated, the first two by fractionation with ammonium sulphate and the last by coagulation from extracts from which the globulins have been precipitated by prolonged dialysis.

The proteins are sharply distinguished by their different sulphur and nitrogen content, by differences in the percentages of the basic amino acids, as determined by Van Slyke's method, and by the fact that the β-globulin does not give the Hopkins-Cole reaction for tryptophane. The latter observation is of particular interest inasmuch as this amino acid has been found in all seed globulins heretofore tested. Both the α-globulin and the albumin from the Georgia velvet bean contain tryptophane.

THE CHEMICAL COMPOSITION OF COTTONSEED OIL.[5]

By George S. Jamieson and Walter F. Baughman.

[ABSTRACT.]

AN investigation was undertaken to determine quantitatively the fatty acids occurring in measurable amounts in cottonseed oil, the composition of which has been a subject of controversy for many years. Cold pressed oil from Sea Island cotton, obtained by means of the expeller, was used for this study. It contained

[4] Published in *J. Biol. Chem.*, **42** (1920), 59.

[5] Published in *J. Am. Chem. Soc.*, **42** (1920), 1197.

23 per cent. of saturated acids and 72.5 per cent. of unsaturated acids as determined by the lead-salt-ether method. The iodine value (Hanus) of the unsaturated acids was 142.2, the saponification number was 199.4, and the mean molecular weight was 281.3.

In addition to the separation and identification of stearic and arachidic acids, a small amount of myristic acid was found which has not been previously reported as occurring in cottonseed oil.

The following table gives the percentages of the acids found from which the corresponding glycerides were calculated:

Acid.	Per cent in Original Oil Acids.	Per cent in Original Oil Glycerides.
Myristic	0.32	0.34
Palmitic	19.10	20.04
Stearic	1.90	1.96
Arachidic	.56	.58
Oleic	33.15	35.17
Linolic	39.35	41.74

Galvanomagnetic Effect Parallel to the Lines of Force and Perpendicular to the Current. LA ROSA and A. SELLERIO. (*Comptes Rendus*, June 14, 1920.)—If an electric current flows along a sheet of bismuth, the ends of two wires joined to a galvanometer may be put in contact with two points on the bismuth so located that they are at the same potential. In this case no current flows through the instrument. If, now, a strong magnetic field is applied with its lines of force at right angles to the sheet of bismuth, a current shows itself in the galvanometer. The magnetic field has distorted the lines of flow of the current (Hall effect).

The two experimenters placed a cylinder of bismuth between the poles of a Weiss electromagnet with its axis parallel to the lines of force. A current was sent from one side of the cylinder to the other and the ends of the wires from the galvanometer were soldered to points on the end of the cylinder which were at the same potential, when the magnetic field was absent. When the field was excited there was a permanent deflection of the galvanometer, which was reversed in direction when the field was reversed. The deflections in the directions were by no means alike in size. The authors conjecture that there are two effects superimposed, one of which reverses with the field while the other does not. The difference between this new phenomenon and the Hall effect is in this, that in the latter the effect is perpendicular to the direction of the current, while in the newly discovered effect it is manifested along the magnetic lines of force.

G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.*

ACCIDENT PREVENTION IN THE MINES OF BUTTE, MONTANA.

By Daniel Harrington.

An investigation of the health and safety conditions in the Butte district has been conducted by the Bureau in coöperation with the U. S. Public Health Service. In Butte the problem of safeguarding from accidents has been a difficult one, because of the great depth and extent of the mines, the large labor turnover, and during the war, the intensity at which the mines were worked.

Some of the companies have expended much money and effort in developing safety organizations and in safety and welfare work. Hence this investigation, covering one of the most important metal-mining centres, where safety organizations and work have been brought to a high plane by some of the companies, is of special interest. It was found that the results obtained were commensurate with the effort expended, not only in decrease of accidents, but in the large financial saving to the companies. For example, one large company specializing in fire prevention had no serious losses from fire; another specializing in prevention of injuries had a comparatively low accident rate, and another specializing in ventilation, has converted a "hot" mine into one of the most comfortable and sanitary in the district.

Technical Paper 229, "Accident Prevention in the Mines of Butte, Mont.," recently issued by the Bureau, is a detailed report on the investigation.

EFFECTS OF GASOLINE REMOVAL ON HEATING VALUE OF NATURAL GAS.

By Donald B. Dow.

The question as to the loss of heating value of natural gas through the removal of the gasoline vapor that the gas contains, has caused much controversy, in which the public in general and

* Communicated by the Director.

legislative bodies and public ultilities commissions have taken part. Notwithstanding the several sources of information available, the general understanding in regard to this question remains unsettled.

In the hope that this uncertainty may be removed, the Bureau of Mines has made a comprehensive investigation of the problem through its petroleum station at Bartlesville, Okla. The natural gas examined included gas being treated at gasoline plants in many different fields, not only "dry" gas treated by absorption, but also rich "casing-head" gas treated by this method, in order that definite information might be available as to the effect of recovering gasoline from natural gas of varying richness and from different localities.

In general, the decrease in heating value of natural gas from removal of the gasoline vapor is overestimated. The loss in the B. t.u. value of the "dry gas" ordinarily supplied to the domestic consumer was found to be about 2 per cent. after the gasoline vapor had been removed, but for "casing-head" gas, which rarely reaches the domestic consumer, the percentage loss is larger. As the gasoline vapor in natural gas is usually accompanied by proportionate amounts of other constitutents of high heating value, a high gasoline content usually indicates a gas of high heating value even after the gasoline has been removed.

The detailed results of the investigation are presented in Technical Paper 253.

USE OF STENCHES AS A WARNING IN MINES.

By S. H. Katz.

AN investigation by the Bureau on the use of stenches in the compressed air lines as a means of warning miners in the event of imminent danger, has shown that the method is of great practical value. Stenches were tried in the Bureau's laboratories and in the experimental mine, and later large-scale tests were made in a number of metal mines. Of the chemicals tried, the best were butyl mercaptan, ethyl mercaptan, butyric acid and amyl acetate.

Technical Paper 244, "Use of Stenches as a Warning in Mines," by S. H. Katz, V. C. Allison, and W. L. Egy, gives the results in detail.

PHYSIOLOGICAL EFFECTS OF CO.

Plans are being made to extend work on effects of CO in small quantities on men in confined spaces, being conducted by the Bureau at Yale University for the New York and New Jersey State Tunnel Commission, to include a general study of effects of CO and associated gases on men working in mines and metallurgical plants.

OIL-SHALE COMPOSITION.

Microscopic examination by Dr. R. Thiessen at the Pittsburgh laboratory of the Bureau, of oil shales from Illinois, Utah, Colorado, and Nevada, indicate that the oil distilled from the shale is not present in the shale as oil, but as original plant matter or as degradation products of plants.

A quantitative method for the determination of vitamine has been devised by Roger J. Williams (*Journal of Biological Chemistry*, 1920, xlii, 259–265). The method is for the quantitative determination of the vitamine which prevents beriberi. A synthetic medium is prepared, each litre of which contains 20 grams cane sugar, 3 grams ammonium sulphate, 2 grams monopotassium phosphate, 1.5 grams asparagine, 0.25 gram calcium chloride, and 0.25 gram magnesium sulphate. One hundred c.c. of this medium is diluted to a volume of 110 c.c., sterilized, inoculated with a suspension of fresh compressed yeast in sterile water containing 0.3 milligram of yeast and having a volume of 1 c.c. The culture is incubated for eighteen hours at a temperature of 30° C.; growth is stopped by addition of formaldehyde solution; the yeast is collected by filtration of the culture through a weighed Gooch crucible, washed with water and with alcohol, dried for two hours at a temperature of 103° C., and finally weighed. This is the control experiment, and the yield of yeast is approximately 2.5 milligrams. At the same time, 100 c.c. of the synthetic medium and a definite volume of an extract representing a definite weight of the substance to be tested for vitamine are mixed, diluted to a volume of 110 c.c., sterilized, sown with the yeast as already described, and then treated in exactly the same manner as the control experiment. The yield of yeast above that in the control is a measure of the vitamine content of the substance tested. "The 'vitamine number' of a material may be defined as the number of milligrams of yeast produced by the addition of its extract minus that produced in a control solution, under given conditions and within certain limits, computed to 1 gram of the original material tested."

J. S. H.

Scientific problems of cold storage industries are discussed by W. B. HARDY in the *American Society of Refrigerating Engineers Journal*, 1919, vi, 201–208. One problem is the storage of fruits and vegetables which are actually alive when harvested. If they are to be preserved in any semblance of their normal selves, they must be kept alive. While their duration of life may be lengthened, no method yet tried will do more than double their natural life. The duration of life may be increased (1) by use of cold storage which retards the chemical processes in the living matter, or (2) by controlling the oxygen supply and thereby decreasing the total respiration. However, interference with the normal respiration may so modify the chemical changes in fruit as to render the latter unfit for food; thus strawberries preserved in this manner may produce amyl alcohol. Another problem is the freezing of beef for cold storage in such a manner that it does not drip on thawing. When beef is frozen in air by the usual procedure, the relation of the solid and liquid constituents of the muscle is so altered that a considerable amount of liquid drips from the carcass on thawing. During freezing the solid constituents are first separated from the liquid and the latter is then solidified. Now, if beef muscle be frozen sufficiently rapidly, this separation of the solids from the liquid does not occur, and dripping does not take place on thawing; the normal character of the muscle is also preserved. For rapid freezing the medium surrounding the beef must be denser than air, and must have a high specific heat. Satisfactory results have been obtained in laboratory experiments, and the process must now be developed on a commercial scale. Other problems which may be mentioned are: The measurement of heat flow through insulating materials; the determination of humidity at low temperatures; the construction of insulated lighters to convey produce from ships to storage plants; and the relation of the fats and oils of stored perishables to changes in their flavor. J. S. H.

Detection of Coal-tar Dyes in Butter and Oleomargarine.—G. VAN B. GILMOUR (*Analyst*, 1920, xlv, 173) has devised the following test: The fat is separated from the melted sample by filtration; the temperature must not exceed 100° C. Approximately 1 c.c. of the fat is placed in a test tube which is then placed in an oil bath. The temperature of the bath is raised to approximately 185° C. The test tube is occasionally removed, shaken, and replaced in the bath. If the fat contains only vegetable butter colors or the natural pigment of butter, it will become colorless within ten minutes at a temperature of 180° to 190° C. If the fat remains colored, coal-tar dye is present. However, butter-fat separated at a temperature above 100° C. will not become colorless on heating.

J. S. H.

THE FRANKLIN INSTITUTE.

MEMBERSHIP NOTES.

CHANGES OF ADDRESS.

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NECROLOGY.

Mr. W. Lyman Biddle, 428 Chestnut Street, Philadelphia, Pennsylvania.
Mr. Samuel Gibson Dixon, 2d, Montgomery Avenue, Ardmore, Pennsylvania.

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BOOK NOTICES.

TRAITÉ DE LA LUMIÈRE, PAR CHRISTIAN HUYGHENS. 12mo., 153 pages, contents and 74 illustrations. Paris, Gauthier-Villars et Cie, 1920. Price, 3f 60, in paper.

This is the first volume of a series of reprints of epoch-making publications of scientists of earlier days, the title of the series being "Les Maîtres de la Pensée Scientifique." The general editorial supervision is by Maurice Solovine. The reprint is preceded by an editorial note summarizing the life and work of Huyghens, from which we learn that he was born at The Hague in 1629 and died in 1695. His father was a statesman and poet. Christian's progress in education was rapid, and at the age of sixteen he wrote a paper on a mathematical subject which was commended by Descartes.

The particular paper reprinted in this volume was published in 1690, in which also appeared his "Discours sur la cause de la Pesanteur." The prospectus of the series gives a long list of essays by famous scientists, mostly physicists and mathematicians and principally of Continental Europe, but including the works of Newton, Faraday, Young and Herschel. Some biologic essays are listed. A perusal of memoirs of earlier workers is of interest and advantage to the student and should be encouraged by teachers. One feels often, in reading the essays of scientists or philosophers of several centuries ago, the force of Chaucer's lines:

> "For out of the old fieldes as men saithe,
> Cometh al this new corne fro yere to yere;
> So out of old bookes in good faithe,
> Cometh al this new science that men lere."

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 63. Results of Tests on Radiators for Aircraft Engines. Preprint from Fifth Annual Report. 34 pages, illustrations, diagrams. Quarto. Washington, Government Printing Office, 1920. The work is divided into two parts.

Part I shows in tables and curves the results of measurements of geometrical characteristics of 59 types of radiators, together with such physical properties as heat transfer, head resistance, air flow through the core, power absorbed, and figure of merit. In most cases the properties are shown for speeds running up to 120 miles per hour.

The terms used in describing the radiators and their performance are defined, the more evident relations between the properties and characteristics are stated, and applications of the results to the design of a radiator are pointed out.

It is shown that the most efficient type of radiator tested, for use at high speeds and mounted in "unobstructed" positions on the aircraft, is one whose water tubes are flat hollow plates, placed edgewise to the air stream, and continuous from front to rear of the radiator.

Part II shows in curves the pressure heads required to produce given rates of flow of water in twelve sections of radiator, each of a different type, briefly described and shown in photographs, but each with a core

eight inches square. The methods used in the tests and in computation are stated in detail, and a method is developed for estimating, by the use of twelve sets of auxiliary curves, the pressure head required for a given rate of water flow in each type of radiator, when of any size, on the assumption that losses of head at inlet and outlet of the water tubes are negligible in comparison with the resistance in the tubes of the eight-inch sections.

Report No. 65, The Kiln Drying of Woods for Airplanes. Preprint from Fifth Annual Report. 31 pages, illustrations, plates. Quarto. Washington, Government Printing Office, 1920.

The exigencies of the war and scarcity of air dried material necessitated kiln drying stock immediately from the green condition. Exhaustive experiments and tests made by the Forest Products Laboratory during the last ten years have established the fact that properly kiln dried wood is just as strong, tough and stiff as the best air dried material. Douglas fir wing beams may be dried in 18 to 24 days. To air dry the same material requires 12 to 18 months. Hardwood propeller stock, which requires a year or more for air drying, may be satisfactorily kiln dried in 30 days. The important qualities of dried wood are freedom from checks, honeycombing, or casehardening; uniform moisture distribution; maximum strength and toughness; freedom from collapse and warping; and minimum shrinkage.

The microscopic structure of wood is briefly described; also the way in which moisture is contained in wood, and the properties and behavior of wood upon removal of moisture.

Methods of controlling the circulation, humidity and temperature in the various kilns are discussed; also the use of instruments for determining actual conditions within the kiln.

The method of piling the lumber within the kiln has much to do with the factors of circulation and control of conditions. In order to know what is taking place, a suitable method of sampling and testing the material during the progress of drying must be instituted, and definite records kept of the process. These points are fully discussed. Methods for removal of casehardening and prevention of mold are described.

The appendix contains the Signal Corps specifications for kiln drying airplane stock, a constant dew point schedule for Douglas fir, spruce and similar woods, and a brief description of the Forest Service water spray dry kiln.

Report No. 73. The Design of Wind Tunnels and Wind Tunnel Propellers. Preprint from Fifth Annual Report. 24 pages, illustrations, diagrams. Quarto. Washington, Government Printing Office, 1920.

This report is devoted to the study of theory of wind tunnels and wind tunnel propellers, and to an analysis of present-day practice in wind tunnel propeller design. The application of the blade element method of design is also discussed. The conclusion is reached that large tunnels giving a moderate air speed are in general preferable to small tunnels of very high speed. The losses in the exit cone are charted in accordance with Eiffel's investigations, a set of curves being constructed

which permit the immediate determination of the approximate efficiency of a projected design of tunnel.

The concluding portion of the report deals with model wind tunnel experiments, including both the efficiency of the tunnels and the regularity of distribution of air-flow across the section. The conclusion is reached that the Eiffel type of tunnel is much inferior to one with a continuous closed tube.

Report No. 77. Preprint from Fifth Annual Report. 41 pages, illustrations, plates. Quarto. Washington, Government Printing Office, 1920.

The purpose of this report is to describe the work done by Mr. H. F. Parker, in the development of a wing permitting of variation of the camber and having wider range of usefulness than is possible at a single section. The Parker rib contains two sets of diagonal wires, one of which is normally slack, and a considerable motion is possible between the extreme positions where the two sets of diagonals become taut. The report describes statical tests for strength on ribs constructed in this manner. These tests were very satisfactory, the ribs comparing favorably in strength with those built up rigidly in the ordinary way. A series of aerodynamic tests on sections of the various forms which the Parker wing would assume in passing from one extreme position to the other are also included, the wings having been tested as monoplanes and in biplane and triplane combinations of various types. The maximum absolute coefficient for the Parker wing at its high-lift setting was .77, while the minimum drag coefficient for a wing of the form which the Parker wing has with the other set of diagonals taut (the form then being approximately symmetrical about a centre line) was .007. The ratio of maximum lift to minimum drag coefficient was, therefore exceptionally high.

Report No. 80. Stability of the Parachute and Helicopter. Preprint from Fifth Annual Report. 11 pages, illustrations. Quarto. Washington, Government Printing Office, 1920.

This report deals with the mathematical theory of the stability of bodies normally travelling vertically, especially with aircraft symmetrical about a vertical axis, as is the case with the ordinary parachute. The treatment is based on the method of Bryan and Brodetsky. It is pointed out that the parachute may have a compound oscillation of a complex form, and some of these oscillations are illustrated. The conditions of stability are deduced, and rules and a chart are given which make it possible to predict the degree of stability for any parachute for which the resistance and rotary derivatives and other characteristics have been determined by wind tunnel test or otherwise.

Copies of the above reports may be obtained from the Committee.

PUBLICATIONS RECEIVED.

Spot and Arc Welding, by H. A. Hornor, B.A.: 296 pages, illustrations, plates. 12mo. Philadelphia, J. B. Lippincott Company, 1920.

National Advisory Committee for Aeronautics: Fourth Annual Report, 1918. 654 pages, illustrations, plates. Quarto. Technical Notes No. 5,

Relation of Rib Spacing to Stress in Wing Planes, by A. F. Zahm. 5 pages, illustrations, plate. No. 6, Static Testing and Proposed Standard Specifications, by E. P. Warner. 17 pages, illustrations. No. 7, Notes on the Design of Supercharged and Overdimensioned Aircraft Engines, by Schwager. 6 pages, diagrams. Washington, Government Printing Office, 1920.

Hydration as an Explanation of the Neutral Salt Effect, by John Arthur Wilson. 6 pages, illustrations, 8vo. (Reprinted from the *Journal of the American Chemical Society*, April, 1920.)

The Railroad Situation. The Duty of Every Newspaper: A Letter to Members of the Southern Newspaper Publishers' Association, by Victor H. Hanson. 11 pages, 8vo. New York, Association of Railway Executives, 1920.

Missouri School of Mines: Catalogue, 1919–1920. 164 pages, illustrations, 8vo. War Records. 88 pages, plate, 8vo. Rolla University, 1920.

U. S. Bureau of Mines: Bulletin 112. Mining and Preparing Domestic Graphite for Crucible Use, by George D. Dub and Frederick G. Moses, with a chapter on Methods of Analysis Used by the Bureau of Mines, by G. B. Taylor and W. A. Selvig. 80 pages, illustrations, plates, 8vo. Monthly Statement of Mine Fatalities in the United States, April, 1920, by W. W. Adams. 8 pages, 8vo. Washington, Government Printing Office, 1920.

True Tanning Value of Vegetable Tanning Materials, by John Arthur Wilson and Erwin J. Kern. 12 pages, illustrations, 8vo. (Reprinted from the *Journal of Industrial and Engineering Chemistry*, May, 1920.)

Present Status of the Refrigerating Industry in Russia.—According to NICHOLAI BORODIN (*American Society of Refrigerating Engineers Journal*, 1919, vi, 190–195), at the beginning of the World War, Russia contained 343 plants provided with mechanical refrigeration, in addition to numerous large cold storages for butter and fish which were refrigerated by means of ice. The total mechanical refrigeration amounted to approximately 28,000,000 normal calories. During the war, the cold storage plants were increased in number. Seventeen slaughter houses were constructed; each had a daily capacity of 150 head of horned cattle, and was provided with the means of freezing and storing the meat; two of these houses have been destroyed by fire. The army also constructed seven cold storage plants each with a capacity of 30,000 pounds of meat, and four plants with a refrigeration capacity of about 800,000 calories each. Of the latter plants, each was attached to a slaughter house intended to handle 500 head of cattle as well as some sheep; machinery for them was obtained from breweries. When political and economic conditions in Russia become settled a great demand will exist in that country for refrigerating machinery, cold storage equipment, and refrigerator cars.

J. S. H.

CURRENT TOPICS.

Carbon Dioxide Content of Milk.—LUCIUS L. VAN SLYKE and RICHARD F. KEELER of the New York Agricultural Experiment Station at Geneva have made a research on "The Carbon Dioxide Content as a Basis for Distinguishing Heated from Unheated Milk" (*Journal of Biological Chemistry*, 1920, xlii, 41-45). Normal milk in the udder has an average carbon dioxide content of approximately 10 per cent. by volume. Immediately after the milk is drawn from the udder, either by hand or by a milking machine, its carbon dioxide content usualy lies between 4 and 4.5 per cent. by volume. When fresh milk was allowed to stand, its carbon dioxide content decreased and attained a minimum value of 3 per cent. by volume from twenty to forty hours after milking. Agitation, such as milk may undergo on the farm and during marketing, had little or no effect in reducing the per cent. of carbon dioxide in the milk. After pasteurization by the flash system or by heating for thirty minutes at either 62° or 78° C., milk seldom contained more than 2.5 per cent. carbon dioxide by volume, and usually contained less. "Therefore, it appears safe, in general, to assume that milk containing less than 2.5 or 3 per cent. of carbon dioxide by volume has been heated to the temperature of pasteurization."

J. S. H.

Tests of Auxiliary Condensers. C. WALDIE CAIRNS and J. MORROW. (*North-East Coast Institution of Engineers and Shipbuilders*, May 17, 1920.)—The paper is based on a report to the Council by the authors, on tests carried out by them for the purpose of determining the relative performances of certain auxiliary condensers for use on board ship. Four condensers were tested, *viz.*, two of "Contraflo" type, one of cylindrical, and one pear-shaped.

The particular condensers are described in detail. The experiments conducted are described and comparative tables of the results from the tests made upon each condenser are given. A statement of conclusions from these results completes the report.

The Existence of Homogeneous Groups of Large Ions. O. BLACKWOOD. (*Proc. Nat. Acad. Sciences*, May, 1920.)—When distilled water is sprayed large ions are produced, whose exact nature is as yet unknown. It is maintained by some that these ions are of only a few definite sizes.

This was investigated by studying the flow of an air stream carrying such ions through the space between two concentric cylinders, between which there was a difference of electrical po-

tential. The electric field imparts to the charged ions a lateral motion and hence the strength of the ionic currents varies with difference of potential maintained. The connection between these quantities was found by experiment and the results were compared with the results calculated on the supposition that there were only three kinds of ions present. The actual and the theoretical results were very different from which the conclusion is drawn. "It has now been shown that, contrary to the findings of other observers, a series of widely separated, well-defined mobility groups does not exist in the ionization from spray. Their hypothesis that the large ion is a complex cluster of stable water molecules may consequently be abandoned in favor of the simpler conception of J. J. Thomson and others, who have pictured the large ion as merely a charged globule of water having a radius of equilibrium which is a function of the humidity of the air."

G. F. S.

Wireless Telegraphy in the British Army. (*Electrician*, June 25, 1920.)—Instruments used at Woolwich are reported to transmit more than 2000 words per minute. A range of 250 miles with an accuracy of one degree of arc is claimed for a new miniature, revolving direction-finder. Moreover, an instrument has been devised for transforming ground line telegraphic signals into wireless with a normal speed of 450 words per minute.

G. F. S.

Activities in the National Physical Laboratory Near London. (*Electrician*, June 25, 1920.)—The laboratories have resumed their pre-war appearance and no parts are closed to the public.

A study of the heating of underground electrical cables has been in progress for several years. It has been found that the thermal conductivity of the dielectric in paper-insulated cables varies considerably with the make. This difference in turn affects the permissible load, since the slower the rate of cooling the higher the temperature becomes. The quantity of moisture in the ground surrounding the cable is another important factor. The drier the ground the slower the dissipation of heat and the greater the rise of temperature in the cable.

For the tests a motor generator giving 5000 amperes at 6 volts is used. To keep the current constant to one-tenth of 1 per cent. this device was employed. The current passes through a resistance whose P.D. is balanced by a potentiometer. In one of the lines to this instrument is a galvanometer reflecting a spot of light upon a scale at the two ends of which are two selenium cells forming two arms of a Wheatstone Bridge. From their junction is connected a polarized relay. When the main current is of the desired strength, the galvanometer does not deflect. When, however, the current changes, the galvanometer deflects and throws

its spot of light on one or other of the selenium cells, thereby changing the resistance of the latter. This upsets the balance in the bridge and causes a current through the relay, which operates other relays varying resistance in circuit with the shunt circuit of the generator. If the main current is too large the spot of light moves in one direction; if it is too small the direction of deflection is in the opposite direction. Different selenium cells receive the light spot in the two cases and the current in the relay has its direction determined accordingly and a different modification of resistance is brought about. This is another of the steadily growing applications of selenium.

G. F. S.

Death of the Italian Physicist, Augusto Righi. (*Revue Scientifique*, June 26, 1920.)—At the age of seventy this distinguished physicist recently passed away. Among his contributions to science are these: The discovery that bismuth in a magnetic field suffers a change of electrical resistance, the confirmation of qualities common to luminous radiation and to electrical waves; investigations of the phenomena of the electrical spark, especially of the spark in the magnetic field, and a critique of the Michelson-Morley experiment on which is based the modern theory of relativity. It was in his laboratory that Marconi made his early experiments on wireless telegraphy. In announcing the death of Professor Righi to the Paris Academy of Sciences the President, Henri Deslandres, said: "Professor Righi is one of the foremost physicists of our age. He directed his activities toward the most varied subjects and his name is connected with all the great questions of natural philosophy which have arisen in recent years. On those points which he approached he left his profound and original impress."

The chair of Physics in Bologna was held for many years by this worthy successor to the Italian tradition in this science established by Galileo.

G. F. S.

The Functions of Intensity and Phase in the Binaural Location of Pure Tones. G. W. STEWART. (*Proc. Nat. Acad. Sci.*, April, 1920.)—The two ears of a person are in general at different distances from the source of sound and hence receive sound waves of different intensities. It is obvious to regard this difference at the ears as a possible factor in locating the source of sound. After careful experimental examination Professor Stewart reaches this somewhat surprising conclusion: "The intensity effect cannot account for the ability to locate sounds. It does not appear to be even an important factor." He finds, however, that the difference of phase at the two ears is the controlling factor in forming the judgment of location, at least in the case of pure tones, such as

those of a tuning fork. The ears in some way perceive a difference between sound wave and another of the same pitch which is ahead or behind the first in its cycle of motion. This ability to notice phase difference ceases when the frequency of the sound is from 1200 to 1500 double vibrations per second. The results just summarized are not in accord with the views generally presented in psychological literature.

G. F. S.

The Most Powerful Gas Engine in the World. (*La Nature*, June 19, 1920.)—This distinction is claimed for an engine made by the Cockerill Society in Liege, Belgium. In August, 1914, it was in process of erection. The Germans after the capture of the city allowed it to be put into operation and, when they were assured of its success, took it from its owners and sent it into Germany, to Duisburg, where it was running at the time of the Armistice. It was then sent back to Liege, where it was installed for the second time, with the addition of some improvements. It develops 8000 horsepower. The cylinders, four in number, are 1.3 m. in diameter, 1.5 m. stroke, 94 r.p.m. The heat of the gases coming from the engine is used to generate steam for a turbine.

G. F. S.

Observatory of Terrestrial Magnetism in Western Australia. J. A. FLEMING and W. F. WALLIS. (*Ter. Magnetism*, March, 1920.)—Owing to the energy and well-laid plans of Dr. L. A. Bauer the general magnetic survey of the earth is within sight of completion. The next step in the campaign of the Department of Terrestrial Magnetism of the Carnegie Institute of Washington is the promotion of additional observatories in various parts of the earth. The dearth of such observatories in the southern hemisphere led to a search for a suitable site in Australia. The place finally selected is 12 miles west of Watheroo on the Midland Railway, 132 miles from Perth. The Government of Western Australia generously donated 240 acres of land for the observatory.

Several lines of work will eventually be conducted at the institution and for each certain definite qualities are needed in the site.

A. Terrestrial Magnetism.
- *a.* Freedom from sources of artificial magnetic disturbances.
- *b.* Uniform distribution of magnetism.
- *c.* Reasonably dry climate.

B. Atmospheric Electricity.
- *a.* Remoteness from towns.
- *b.* Nearness to sea level.
- *c.* Presence of a flat space near observatory.
- *d.* Absence of trees, shrubs, etc.
- *e.* Distance to sea not greater than 50 miles.

C. Earth Currents.
  a. Possibility of laying two cables at right angles to each other for lengths of ten miles.
D. Solar Constant Observations.
  a. Dry climate and small rain fall.
  b. Location at some distance from sea coast.
E. General, Meteorological, Seismological, and Office Routine.
  a. Accessibility for supplies and mail.
  b. Good water for photographic work.
  c. Telegraph or telephone connections.
  d. Comfort of the observers.

Not all types of work have been provided for up to the present. Observations in terrestrial magnetism began on January 1, 1919, and meteorological data also are obtained.

G. F. S.

Petroleum in France and Her Colonies. (*La Nature*, May 22, 1920.)—Since the scientifically executed destruction of the coal mines in northern France by the Germans, the question of fuel has become a vital one in this country. Now she is entirely dependent on importation for her supply of oil. Even this is precarious owing to the increasing use of liquid fuel and of gasoline. To provide for the future a search is being made for sources of petroleum within her own territory. In several parts of France promising indications of oil have been found. In Isere sandstone 32 inches thick is impregnated with petroleum. Already in Algeria oil is produced on a small commercial scale. The same is true in Tunis, and there is some reason to believe that Madagascar and Indo-China may have oil beds.

G. F. S.

The Commercial Application of Electrical Osmosis. J. S. HIGHFIELD, W. R. ORMANDY, and D. NORTHALL-LAURIE. (*Journ. R. Soc. Arts*, June 25, 1920.)—A colloidal solution, or sol, of clay can be clarified by immersing in it two electrodes attached to a source of electrical potential. The clay particles then travel to the anode, where they give up their electric charges and form a coagulated mass. The water of the sol is driven to the cathode. The finely divided impurities, such as silica, mica, and pyrites, are either carried away by the flow of water or are collected at the cathode. In the actual machine the clay suspension enters the lower part of a tank and is urged by paddles through a perforated cathode which surrounds the anode. The latter is a metal cylinder revolving slowly at a distance of three-quarters of an inch from the other electrode. Clay collects on the anode, is removed by a scraper and falls down a chute away from the machine. One thousand tons of pure clay per year is produced by a machine with a cylinder five feet long and two feet in diameter. The clay leaves

the machine as a sheet one-fourth to one-half inch thick and contains only 25 per cent. of water. It is possible to treat many varieties of clay by this process.

Among the advantages derived from this method of preparation are these:

a. Saving of fuel, since the finishing of articles made from clay thus obtained can be completed at lower temperatures than with ordinary clays.
b. Articles can be made which show little contraction after burning. This is because the sintering temperature is lowered and the fusing point raised by this method of preparation.
c. Vitrified bricks and roofing can be made from material which otherwise could not be employed for this purpose.
d. Whiter porcelain and earthenware are got from osmosed clay than from ordinary clay. Pyrites and other sources of discoloration have been removed.

Electrical osmosis is applicable also to the tanning of leather, the treatment of metal slimes and the removal of ash from gelatine.

G. F. S.

Spontaneous Evaporation. H. B. WEISER and E. F. PORTER. (*J. Phys. Chemistry*, May, 1920.)—In 1859 Babington published the results of a series of investigations on the rate of evaporation of salt solutions. One of his conclusions was this: "There are some salts which, being dissolved in water, do not retard evaporation, and some salts which, so far from retarding, actually accelerate evaporation." This result seemd so unlikely that it was thought well to repeat the experiments on which it rested. This was done, great care being taken to have uniform conditions of evaporation for water and for the salt solutions, and to avoid the creeping of the latter. The same salts were used as in Babington's work, but in no case did the evaporation of a solution exceed that of water. When the solutions were permitted to creep up the sides of the vessels and thus to increase the area of the surface for evaporation it was observed that water evaporated less rapidly than the solutions. As Babington used saturated solutions the creeping effect was, no doubt, far from negligible in his experiments.

G. F. S.

Foreign Constituents in Unscoured Wools.—*The Weekly News Letter of the United States Department of Agriculture* for June 30, 1920 (vol. vii, No. 48, pages 1–2) reports the amounts of foreign constituents which were found to be present in seventy-three samples of wool, some of domestic, others of foreign origin. Very little potash was present in pulled and washed wools. Lower grade wools apparently contained more potash than the fine grades. Unscoured wools with a low grease content were richer

in potash than those with a high grease content. Even in the same grade or class of wool, the foreign constituents varied within wide limits. Thus Ohio delaine, a very greasy wool, contained from 17.8 to 41.9 per cent. grease, from 2.5 to 4.6 per cent. moisture, from 14.9 to 38.7 per cent. ash. The extractives (water extract) soluble in water after removal of the grease, the nitrogen content of that extract, and its potash (K_2O) were all calculated as per cent. of the unscoured wool. In Ohio delaine, the water extract varied between 6.3 and 17.1 per cent., the nitrogen content of the water extract between 0.3 and 0.8 per cent., and the potash content between 1.1 and 4.7 per cent. The grease is used in the manufacture of lanolin, and probably may be utilized in leather dressing, waterproofing, and varnish. Potash and fertilizer may also be obtained as by-products of wool-scouring.

J. S. H.

Formation of Ferrous Sulphide in Eggs During Cooking.—CHARLES KENNETH TINKLER and MARION CROSSLAND SOAR (*Biochemical Journal*, 1920, xiv, 114–119) find that the greenish-black coloration on the surface of the yolk of a "hard-boiled" egg apparently is due to the formation of ferrous sulphide. The hydrogen sulphide which is necessary for the formation of ferrous sulphide is produced by the decomposition of a sulphur compound in the egg white. The coloration does not occur if the hard-boiled egg be placed in cold water immediately after cooking, since the decomposition of the sulphur compound is checked by the cooling.

J. S. H.

Antiscorbutic properties of concentrated fruit juices have been studied by ARTHUR HARDEN and ROBERT ROBISON (*Biochemical Journal*, 1920, xiv, 171–177). Orange juice may be reduced to a dry residue by evaporation under suitable conditions at a low temperature without undergoing an appreciable loss of the antiscorbutic accessory factor or vitamine. This residue retains a considerable degree of potency after storage for two years in a dry atmosphere at ordinary temperatures. The preparation of such dried orange juice on a commercial scale apparently is quite practicable, and should prove of considerable value where an antiscorbutic material is required in a highly concentrated and stable form.

J. S. H.

Making Wood Fire Resistant with Paint. (*Technical Notes, Forest Products Laboratory*, U. S. Forest Service, Madison, Wisconsin, No. 106, 1920.)—Fire retardent paints are the most practical means so far discovered by the Forest Products Laboratory by which small amounts of wood can economically be made fire resistant. The only other known methods of decreasing the inflammability of wood are to keep it wet, or to inject into it certain chemicals

under pressure. These methods, though more effective than painting, are usually either impracticable or too expensive to be considered.

Ordinary calcimine, or whitewash, has proved in tests to be as fire resistant as any paint covering tried. It is cheap and convenient to use. Although it will not prevent the burning of wood exposed continuously to a high heat, a good coat of calcimine on wood will decrease the danger of a blaze spreading from burning cigarettes, sparks, matches, and similar small sources of fire. Calcimine is, of course, more effective for inside than for outside use.

For exterior use numerous patented fire retardent paints are available. An effective outdoor paint which has been developed at the Forest Products Laboratory consists of linseed oil, zinc borate, and chrome green. This paint has maintained its fire resisting properties through more than three years of exposure to the weather.

Transportation by Air between Paris and London. (*Le Genie Civile,* June 26, 1920.)—Beginning with August 25, 1919, two companies, one French and the other British, inaugurated daily trips from one capital to the other by airplane. Since the date mentioned two additional French companies and one other English concern have established similar services. The distance is about 400 km., and the trip takes from two to three hours in general. The best time is a little less than two hours. The early afternoon is the time of the flight. From 500 to 700 francs are charged for a trip and excess baggage costs about 9 franc per kg.

From August 25, 1919, to June 2, 1920, in all 1074 single trips were made, 1041 sacks of mail were carried with 1641 passengers and 38,860 kg. of merchandise. This means of crossing the English Channel is growing in favor, five times as many passengers having been carried in May, 1920, as in November, 1919. In this service airplanes with two or four places are the rule, though some have large cabins with room for as many as a dozen people.

G. F. S.

The Meeting of the French Society for Gas Technology. (*Le Genie Civile,* June, 1920.)—A prevalent note was the need of economy in view of the serious fuel shortage in France. M. Rolland d'Estape discussed the use of lignite for the manufacture of gas. He finds it possible to use this low-grade fuel in modern ovens, but regards it as a very poor substitute for coal, since it lowers the output of the plant and introduces elements of danger due to its coming from the coking process in the form of a powder.

The same speaker reported that in Marseilles the gas pressure was reduced from 60 mm. to 25 mm. and even to 10 mm., but the consumption came down only 10 per cent., as the consumers managed to burn almost as much gas in spite of the small pressure.

A different report came from Paris where the lowering of pressure resulted in a distinct lessening of consumption. Such experiments in economy indicate the straits to which the French are driven as the joint result of the destruction of their coal mines by the German invaders, and of the failure of Germany to deliver coal as she promised to do in the Treaty of Versailles.

G. F. S.

Chemical Composition of Cottonseed Oil.—GEORGE S. JAMIESON and WALTER F. BAUGHMAN (*Journal of the American Chemical Society*, 1920, xlii, 1197–1204) have analyzed cold-pressed, refined oil obtained from Sea Island cottonseed. The oil had the following composition: Glycerides of myristic acid, 0.3 per cent.; palmitic acid, 20.0 per cent.; stearic acid, 2.0 per cent.; arachidic acid, 0.6 per cent.; oleic acid, 35.2 per cent.; linolic acid, 41.7 per cent.; total, 99.8 per cent. Linolenic acid was not present in the oil.

J. S. H.

Gas Masks in Pulp and Paper Mills. (*Technical Notes, Forest Products Laboratory*, U. S. Forest Service, Madison, Wisconsin, No. 102, 1920.)—Gas masks of a nose-breathing type, with canisters containing special chemicals, are used in the digester house of the Forest Products Laboratory to give protection against sulphur dioxide. These masks enable the operator to make repairs under conditions otherwise unbearable and soon pay for themselves in time saved. Masks of this type are reported by the Bureau of Mines to hold up against 5 per cent. concentration of sulphur dioxide for about fifteen minutes. When it is realized that five parts of sulphur dioxide to one million parts of air can readily be detected, and that at a concentration of one hundred and fifty parts of sulphur dioxide to one million parts of air the air becomes unbreathable, some idea can be gained of the life of a canister even under adverse mill conditions.

In addition to their use in the sulphite mill these masks are of great assistance in the bleach room, where they are worn continuously during the mixing of the bleach liquor. Aside from monetary considerations, the increased comfort and safety of the workmen is sufficient argument in favor of the addition of gas masks to the regular mill equipment.

Lake Tahoe. (*U. S. Geological Survey, Press Bulletin, No. 451*, July, 1920.)—Lake Tahoe, in California, is often said to occupy an old volcanic crater. This is not a fact. It is true that the region about the lake shows evidence of volcanic activity of various kinds and that the water has at times probably been dammed by outpourings of lava, but the lake itself lies in a structural depression—a dropped block of the earth's crust.

The prehistoric Lake Tahoe was larger and deeper than the

present lake, according to the United States Geological Survey, Department of the Interior. During the Neocene epoch and the earlier part of the Pleistocene epoch its water stood much higher than now, but in its overflow it has since cut through the lava dams that maintained it at that height. Distinct beaches that mark the former higher levels of the lake stand about 100 feet above its present surface, but the water doubtless once stood at even greater heights. At Tahoe City the most distinct of these old beaches is a terrace that stands 35 to 40 feet above the level of the lake. It is on this ancient beach that Tahoe Tavern is built.

Artificial Graphite. (*U. S. Geological Survey, Press Bulletin, No. 451,* July, 1920.)—Graphite is manufactured by the Acheson Graphite Company at Niagara Falls, N. Y. This company utilizes the electric power generated at the Falls to manufacture graphite from anthracite coal or from petroleum coke. This product is used mainly in lubricants, but it is also used in paints, foundry facing, preventives of boiler scale, and fillers for batteries.

Artificial graphite may be used for any purpose for which natural graphite is employed, according to the United States Geological Survey, except in the manufacture of large crucibles. Patents have been issued recently, however, for methods of manufacturing crucibles in which artificial graphite may be used. Artificial graphite is peculiarly adapted to the manufacture of certain graphite products, among them graphite electrodes, which are not made from natural graphite and for which the demand has greatly increased in recent years. The table below, published by permission of the Acheson Graphite Company, represents only the manufactured graphite that comes into competition with natural graphite.

GRAPHITE MANUFACTURED BY THE ACHESON GRAPHITE COMPANY, 1915–1919.

	Pounds.
1915	5,084,000
1916	8,397,281
1917	10,474,649
1918	9,182,272
1919	8,163,177

A Directional Hot-wire Anemometer of High Sensitivity, Especially Applicable to the Investigation of Low Rates of Flow of Gases. J. S. G. THOMAS. (*Proc. Physical Soc. of London,* April 15, 1920.)—Two pieces of platinum wire, 1 mm. in diameter, were stretched across the diameter of a tube. They were parallel to each other with an interval of 1 mm. between them. They were perpendicular to the axis of the tube and the plane containing them was parallel to the direction of flow of the gas. The wires formed the two arms of a Wheatstone bridge. They were traversed by a current which raised the temperature to about 300° C.

The bridge was balanced with the air in the tube at rest. The current of air was then started. The two wires had their resistances changed to different extents by the moving air and hence the bridge balance was upset. The galvanometer deflected. It was found that the direction of this deflection was reversed upon reversal of the flow of air. This arrangement may, therefore, be used to find the direction of flow. Moreover, the amount of the deflection was found to be proportional to the velocity of flow up to 4 cm. per second. This instrument was developed in the physical laboratory of the South Metropolitan Gas Co., London.

G. F. S.

Propagation of Light in a Gravitational Field. A. O. RANKINE and L. SILBERSTEIN. (*Phil. Mag.*, May, 1920.)—Is the speed of light near the earth dependent upon the direction of the light oscillations? An experimental answer to this question was found. The speeds of two light waves in which the directions of vibration are at right angles to each other came out almost exactly the same. The difference was so small that were the two kinds of light to start from the same point and travel outwards for a second one would outdistance the other by only three hundredths of a millimetre in the long stretch of 300,000 kilometres.

G. F. S.

The Relation Between the Refractivity and Density of Carbon Dioxide. P. PHILLIPS. (*Proceedings of the Royal Society*, A 684, May 1, 1920.)—The L. Lorenz and H. A. Lorentz formula connecting refractivity and density is $\frac{n^2 - 1}{n^2 + 2} \cdot \frac{1}{d} = \text{constant}$, where n is refractivity and d is density. This fits well in most cases, but shows divergencies when large changes of density are investigated.

Doctor Phillips studied the refractivity of carbon dioxide at 34° C.; that is, above its critical temperature. The range of densities was in the ratio of 1 to 7. He found the above expression not to be a constant, but to vary in such a way that its reciprocal is a linear function of the square of the density.

G. F. S.

The Pressure Distribution on the Head of a Shell Moving at High Velocities. L. BAIRSTOW, R. H. FOWLER, and D. R. HARTREE. (*Proceedings of the Royal Society*, A 684, May 1, 1920.)—The problem proposed to themselves by the investigators was one of great difficulty. Any kind of registering pressure-gauge placed within the shell would need to be insensible to a spin of 11,660 r.p.m. and to the shock of landing. This difficulty was avoided by employing a service time-fuse as a manometer. The rate of burning of such a fuse depends on the total external pressure on the vents. In the fuse a train of gunpowder is ignited by a detonator

pellet by the shock when the gun is discharged. The time of burning is taken as the interval from the discharge of the gun to the explosion of the shell.

In the experiments shells were fitted with caps enclosing the fuses. In each cap was a series of holes equidistant from the nose of the shell. The relation between rate of burning and pressure was obtained from a set of experiments made with a fuse body mounted on the shaft of a Laval turbine and run in an air-tight box in which the pressure could be varied.

A series of shells provided with caps pierced with holes was fired along the same trajectory at brief intervals and the time of burning of the fuses was noted. From this and the length of the fuse the rate of burning was deduced and in turn from the rate of burning the pressure was derived at the part of the shell where the holes were located. This last step was made by reference to the laboratory experiments under varied pressure. "At all speeds in the range covered the pressure has a maximum positive value at the nose of the shell. The pressure falls rapidly as the point of observation moves toward the base, and is negative some distance before the cylindrical part of the shell is reached."

G. F. S.

Fine Spun Asbestos. (*U. S. Geological Survey Press Bulletin No. 448*, June, 1920.)—The earliest use of asbestos was for spinning and weaving, to make incombustible thread and yarn rope and cloth, and this has continued to be the most important use of asbestos ever since the days of the Greeks and Romans. Only the best grades can be used for this purpose, according to J. S. Diller, of the United States Geological Survey. Thread can now be spun so fine that it will run about 32,000 feet to the pound.

Centenary of the Industrial Calculating Machine. (*La Nature*, May 15, 1920.)—The Alsatian financier, Thomas, in 1820 brought out the first model of his calculating machine. To celebrate the centennial of this event an exposition of all types of calculating apparatus was held in Paris in June, 1920.

Four great names in the history of calculating machines are claimed for France: Blaise Pascal, Thomas of Colmar, Maurel and Jayet, and Léon Bollée.

G. F. S.

On the Viscosities and Compressibilities of Liquids at High Pressures. J. H. HYDE. (*Proceedings of the Royal Society*, A 684, May 1, 1920.)—In the transmission of power by worm gears pressures come into play between the lubricated surfaces of the order of five tons per square inch. This investigation was designed to obtain information concerning the viscosity of various oils under such conditions. For all oils it was found that the viscosity in-

creases with the pressure. This increase is especially rapid for mineral oils (F. F. F. Cylinder, Victory Red, Bayonne, Mobiloil "A," Mobiloil "BB") above the pressure of five tons per square inch. At high pressures the viscosity is as much as twenty times as great as at atmospheric pressure. For animal and vegetable oils (sperm, "trotter," castor, and rape) the increase in viscosity is not so great. At a pressure of seven tons per square inch these have only from four to five times as great a viscosity as at normal pressure. Furthermore, there is a much greater difference between the oils of the mineral class than between those of the other class.

In all cases the compressibility diminishes with increasing pressure and the value of this quantity is not greatly different from the value for water.

Application of Chronophotography to the Study of the Flow of Water Over a Dam. P. MORIN. (*Comptes Rendus,* May 17, 1920.)—A silvered glass sphere, partly immersed in water, floated along with the current. Sunlight fell upon it and thus a bright source of light was provided. This was photographed along with a scale. The light was shut off at regular intervals by a wheel rotating in front of the camera. The path of the image of the sun was a broken line and the time taken to traverse any portion was known from the rate of rotation of the wheel. The accuracy of the velocity measurement is about ½ per cent.

G. F. S.

Utilization of Tidal Energy. (*Nature,* June 3, 1920.)—The rise in the price of fuel has helped to direct attention both in Great Britain and in France to a study of the methods for getting energy from the rise and fall of water with the tides. The great height of the tides in southwestern England and in western France gives to these countries unusually favorable conditions for such projects of development, since the power which can be obtained from a given area is proportional to the square of the tidal range and since further the cost per horsepower of the necessary machinery diminishes as the working head becomes greater.

The problem is complicated by the occurrence of spring and neap tides. At St. Malo the tidal range of the former is 42.5 feet and of the latter 18 feet. The energy output there is 5.5 times as great at spring as at neap tide.

Various systems of storage have been considered. Compressed air and accumulators seem too costly. A feasible suggestion is to use surplus power to pump into a reservoir at a higher level from which it may flow when need arises. It would, of course, be more economical to employ the power as it is developed.

"Assuming a mean tidal of only 20 feet at springs, and 10 feet at neaps, and adopting the single-basin method of development

with operation on both rising and falling tides, each square mile of basin area would be capable, without storage, of giving an average daily output of approximately 110,000 horsepower-hours. In such an estuary as the Severn, where an area of 20 square miles could readily be utilized with a spring tidal range of 42 feet, the average daily output, without storage would be approximately 10,000,000 horsepower-hours."

It may be well to keep in mind the high tides in the Bay of Fundy.

G. F. S.

Calcium Carbonate in Pharmacy and Medicine.—ADLEY B. NICHOLS enumerates the various forms of calcium carbonate which have been included in the materia medica. Precipitated chalk is precipitated calcium carbonate. Prepared chalk is native chalk purified by elutriation; it is less gritty and more adhesive than the precipitated compound. Calcarea carbonica and corallium rubrum of the homœopathic pharmacopœia are forms of calcium carbonate prepared from oyster shells and the skeleton of the red coral, respectively. Other substances which have served as sources of calcium carbonate are: Crab's eyes, crab's claws, and cuttlefish bone. (*American Journal of Pharmacy*, 1920, xcii, 391–393.)

J. S. H.

Heavy Metals in Foods.—In a study on the Pharmacology of Heavy Metals, WILLIAM SALANT (*Journal of Industrial Hygiene*, 1920, ii, 72–78) states that heavy metals apparently are well borne by the body for a considerable time when taken with food; nevertheless, serious results may follow such ingestion. Hence caution should be exercised in permitting the preparation and sale of foods which contain even small quantities of these metals.

J. S. H.

Self-imposed Inspection of the National Canners' Association is described by H. M. LOOMIS, National Director of Inspection of the Association in the *American Journal of the Public Health*, 1920, x, 521–525. The canners on their own initiative have instituted inspection to improve, standardize, and certify their products. The inspection service and its personnel are under the control of the executive officers of the National Canners' Association, and is supported by an assessment levied on the subscribing canners. Minimum standards of quality have been adopted for canned sardines, corn, tomatoes, string beans, lima beans, peas, pumpkin, sauerkraut, spinach, and fruits. Beginning with the pack of the present year, whenever a standard grade has been adopted by the U. S. Department of Agriculture, the minimum standard for certification by the Association shall not be lower than such

standard grade. Problems relating to the industry are handled by the research laboratory of the Association at Washington and by smaller field laboratories such as have already been established in Maine and in California. At present the inspection certificate is attached to each case of approved canned goods. The placing of a certificate or emblem on each can of food approved by the inspection service is contemplated.

J. S. H.

Cockle-bur Oil.—LELAND B. RHODES (*Journal of the American Chemical Society*, 1920, xlii, 1507–1508) has prepared and analyzed this oil. The burs of the cockle-bur or clot-bur, *Xanthium echinatum*, yield 30.69 per cent. by weight of kernels. The kernels contain 29.89 per cent. oil. The cold-pressed oil, obtained from the kernels, is a drying oil with an iodine number of 140.8 and a saponification number of 190.2. In a test, cockle-bur oil in a film completely dried in five days; pure linseed oil under like conditions required four days to reach the same degree of dryness. The press cake was toxic; guinea pigs, which ate a small amount, died in one day.

J. S. H.

Detection of Formic Acid.—E. COMANDUCCI (*Rend. Acc. Sci. Fis. e Mat. d. Nap.*, 1918, 3a, vol. xxiv, 14) has found that formic acid heated gently with a saturated solution of sodium acid sulphite produces a reddish-yellow liquid, which is characteristic. The test is applicable to formates and in presence of formaldehyde, glycerol, methyl alcohol, and acetic acid. When the liquid to be tested is of the color that the reaction will produce, the following modification has been found to be satisfactory, as it dispenses with the older procedure which was to render the solution acid with sulphuric acid and distil in a current of carbon dioxide.

The modified procedure is to add the solution of sodium acid sulphite and heat carefully to incipient ebullition, cool and add a solution of sodium nitroprusside. The test can be conveniently applied by overlaying the suspected solution with the other, when the presence of formic acid is shown by the production of a green or blue line at the point of contact. A blue precipitate may also be formed later.

H. L.

Uniform Composition of Commercial Stearic Acids and Its Explanation.—BEN H. NICOLET (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 677–679) determined the titer of six samples of commercial stearic acid from five entirely different sources. The titers were surprisingly uniform; and the agreement became startling when they were corrected for the small and varying iodine numbers of the samples, for the maximum

variation in the corrected titers was less than 0.5° C. These titers revealed a remarkable constancy in the ratio of the palmitic acid and the stearic acid to each other in the technical stearic acid; this constancy in ratio was probably due to solid solutions formed between the two acids.

J. S. H.

Experimental Distillation of Kelp at Low Temperatures.—G. C. SPENCER (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 682–684) has made sixteen distillations of dried kelp in an oil-jacketed wood retort at temperatures not exceeding 320° C. Aqueous liquor, tar, and a non-inflammable gas were obtained. The residual charcoal was not sufficiently heated for the good extraction of potash or for use as a filtering medium, therefore kelp must be distilled at a much higher temperature.

J. S. H.

Signal Corps, U. S. A.—In studying the provisions of the Act of Congress approved June 4, 1920, reorganizing the Army, it is found that there will be vacancies remaining in the grade of second lieutenant in the Signal Corps, United States Army, after the officers who served in the World War have been examined and commissioned.

The Signal Corps is charged with the general duty of providing communicational signal service for the Army by means of ordinary telegraphy and telephony, submarine cable, radio telephony, and other instrumentalities.

Signal troops not only operate these instrumentalities, but the Corps is charged with the duty of the research and development of the apparatus employed. For many years the Signal Corps has been one of the Staff Departments of the Army, but on account of the growing importance of the duties of Signal Corps troops, the Congress of the United States, in the reorganization of the Army, made the Signal Corps one of the arms of the line of the Army. The importance of its work in both peace and war in the Army is very great. Speaking of the work done by the Signal Corps in the World War, General Pershing, in an official communication, said:

"The work of the Signal Corps in France stands out as one of the masterful accomplishments of the American Expeditionary Forces."

On account of the wide range of duties, varying from service with troops in the field to research, engineering and development of special apparatus for use of the Army, including that required for meteorology; ultra-violet, infra-red and black light signalling; telegraph and telephone engineering, including simplex, multiplex, and phantom circuits; radio telephony and telegraphy, vacuum tubes, etc., the Signal Corps presents a field which should be attractive to young college men who have the educa-

tional foundation on which to develop along the lines of Signal Corps activities in the Signal Corps technical schools of instruction. In addition to the Signal Corps schools, selected officers are sent each year to Yale University and the Massachusetts Institute of Technology for special courses, the expense of tuition being paid from Signal Corps funds appropriated by Congress for that purpose.

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